Amphibia-Reptilia 38 (2017): 547-553

Home range and habitat use of Beni anacondas (*Eunectes beniensis*) in Bolivia

Paola De la Quintana[1,2], Jesús A. Rivas[3], Federico Valdivia[4], Luis F. Pacheco[2,*]

Abstract. Understanding of snake ecology has increased over the past two decades, but is still limited for many species. This is particularly true for the recently described Beni anaconda (*Eunectes beniensis*). We present the results of a radio-telemetry study of nine (3M:6F) adult *E. beniensis*, including home range, and habitat use. We located the snakes 242 times in wet season, and 255 in dry season. Mean wet season home range (MCP) was 25.81 ha (6.7 to 39.4 ha); while mean dry season home range was 0.29 ha (0.13 to 0.42 ha). We found no relationship between home range size and either snout-vent length, weight, or sex. Beni anacondas seem to prefer swamps, and patujusal, while avoiding forest, and rice fields. However, habitat use by individual snakes seems to vary based on the habitats available within their respective home range. Notably, rice fields were avoided by most snakes, which suggests that this type of habitat is unsuitable for anaconda management.

Keywords: sicurí, Sirionó territory, snake movements, snake translocation, tropical ecology.

Home range and habitat use are meaningful aspects of a species natural history and very important to consider when it comes to conservation of a species (Johnson, 1980). Individuals generally use more intensively a sector of its home range (core area), which covers ~50% of the total space used (Bath et al., 2006), generally characterized by greater availability of important resources to individuals, such as food, shelter, and thermoregulation sites (Huey, 1982). Furthermore, larger snakes tend to have higher energy requeriments (Chappell and Ellis, 1987) and therefore may be expected to have more extensive movements, resulting in the need for larger areas to ensure their conservation.

Eunectes contains four species of large snakes (*E. murinus*, *E. notaeus*, *E. deschauenseei*, and *E. beniensis*) ranging across the Amazonian and Orinoco basins of South America (Reynolds, Niemiller and Revell, 2014). Previous studies have focused on the natural history of *E. murinus* (Rivas et al., 2007a,b; Rivas et al., 2016) and population genetic structure, and management of *E. notaeus* (Micucci, Waller and Alvarenga, 2006, McCartney-Melstad et al., 2012). Available information on the recently described Beni anaconda (*E. beniensis*; locally known as sicurí) is limited to the original description (Dirksen and Böhme, 2005) and a note on cannibalism (De la Quintana et al., 2011). The Beni anaconda is endemic to Bolivia, where it is considered Vulnerable (Embert, 2009) and is listed as Least Concern by the IUCN (http://www.iucnredlist.org).

In this contribution, we present the results of a radio-telemetry study of nine Beni anacondas to assess home range size, and habitat use. Results are presented in the context of understanding the natural history of a tropical predator whose biology is barely being elucidated. Although assessing the effects of translocating snakes was not part of our initial objectives, we had to move most of the studied snakes away from their capture sites, because they were too close to people's homes and might have been

1 - Carrera de Biología, Universidad Mayor de San Andrés, La Paz, Bolivia
2 - Colección Boliviana de Fauna, Instituto de Ecología, Universidad Mayor de San Andrés, PO Box 10077, Correo Central, La Paz, Bolivia
3 - Department of Biology, New Mexico Highlands University, PO Box 9000, Las Vegas NM 87701, USA
4 - Carrera de Biología, Universidad Mayor de San Simón, Calle Sucre y Parque de la Torre, Cochabamba, Bolivia
*Corresponding author;
e-mail: luispacheco11@yahoo.com

 DOI:10.1163/15685381-00003124

otherwise killed. We comment on the effects of this fact on our findings.

The study was conducted at Ibiato (14°48′S and 64° 28′W), within the Sirionó Indigenous Territory in Bolivia, from December, 2009 to December, 2010. The Sirionó territory consists of 52,206 ha of seasonally flooded savannas and higher elevation areas of mainly forest habitat (Townsend, 1996). Maximum average temperature is 31.4°C and the annual precipitation 1520 mm. Based on the dominant plant species vegetation height and water depth, we distinguished six habitat types within the study area: swamps, rice fields, patujusal (dominated by "patujú": *Heliconia* sp.), pajatoruno (dominated by plants with cutting edge leaves), bajío (deep water with grassy vegetation), and forest (fig. 1, Appendix).

Capturing anacondas. To capture anacondas, we searched intensively (3-5 people simultaneously, totaling 324 researcher hours) in water bodies by wading through water, shuffling in water under vegetation, and probing vegetation and water with sticks (Rivas et al., 2007b). However, local people captured most (90%) of the animals as found opportunistically near homes. We secured captured snakes by closing the jaws and putting a cotton sock over the head prior to processing the animal (Rivas et al., 1995).

We measured snout-vent-length = SVL, and total length = TL with 1 cm precision, and body mass with a spring scale with 0.25 kg precision for captured animals. We equipped snakes (SVL > 150 cm) with radio transmitters <0.6% of snake mean body weight (~27 g; Model F1850B, Advanced Telemetry Systems, Inc.), implanted subcutaneously using standardized procedures (Raphael et al., 1996). As mentioned, we relocated all the snakes found near homes in the largest wetland within Ibiato. The wetland had similar habitats to where the snakes were found. We addressed the effect of relocating the snakes by analyzing their movements in relation to their capture sites.

We located the snakes during daylight hours only once per day, in order to reduce pseudoreplication, between December 19, 2009 and April 19, 2010 (when flooding was at the highest), and between October 15, and December 30,

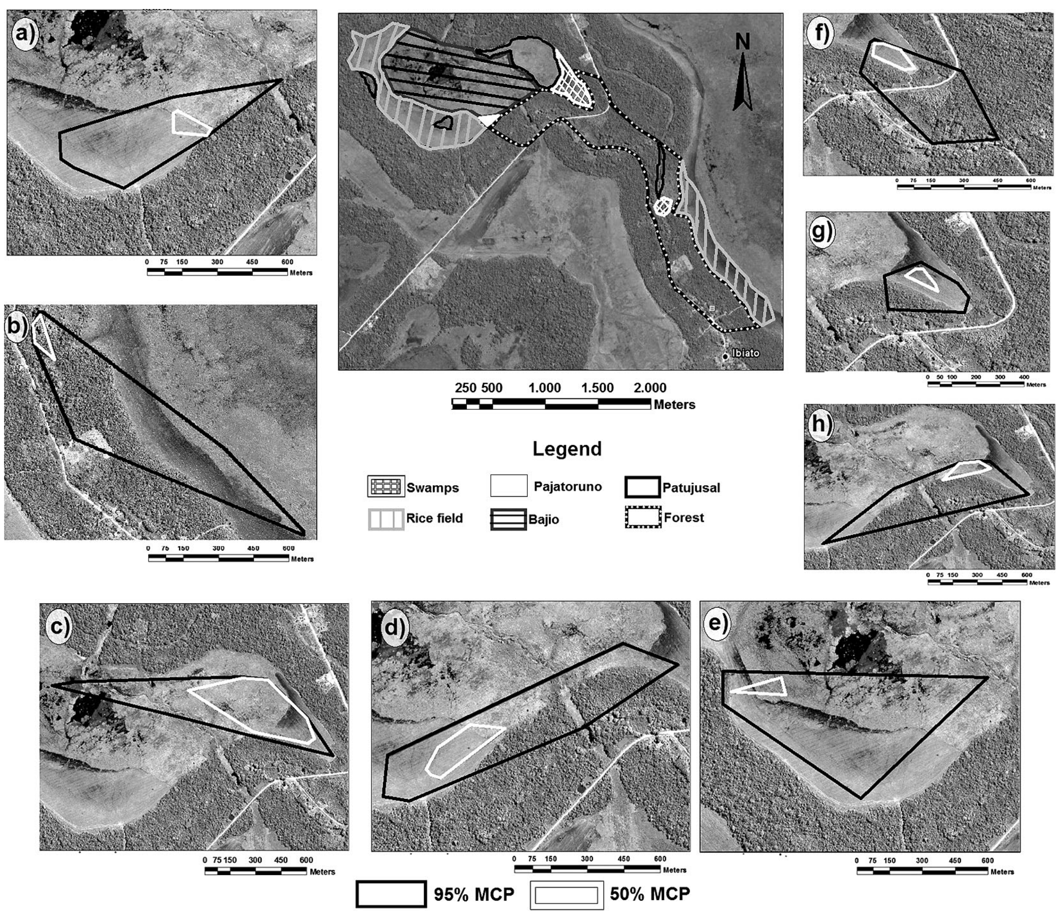

Figure 1. Map showing the six habitat types and the home ranges of eight Beni anacondas in the Sirionó territory, during the wet season. Letters correspond to the snakes in order of appearance in table 1 ("a" is the first female, Martha, "h" is the last male, Carmelo).

2010 (when water level was at the lowest). For each location, we either saw the animal or located it to within 2 m. Once the individual was located, we recorded its UTM position, using GPS unit (datum WGS 84), water depth, habitat type, date, and time (Rivas, 2000).

Home range. Individual locations were entered into the software BIOTAS™ 1.03 Alpha (Ecological Software Solutions™, 2003) and home ranges for wet and dry seasons were calculated. Home range (HR) analyses were carried out using Minimum Convex Polygon (MCP) for snakes with > 15 locations. We estimated core areas with 50% of the locations using bootstrapping, and HR with 95% to avoid the effect of extreme data (Bath et al., 2006, Laver and Kelly, 2008). We did not use kernel method because of the possible flaws of this estimator (Hemson et al., 2005), especially for studies with herpetofauna (Row and Blouin-Demers, 2006).

We used Spearman rank correlations to test for association between snake size (SVL) and HR size, using 95% MCP for the wet season only, given the nature of movements during the dry season. We also did some exploratory analyses, calculating the distances between the HR core areas among seasons, and the distance from core areas to water, to have an idea of the effect of water availability on anacondas' movements. Additionally, we compared daily and weekly wet season movements between sexes.

Habitat use. We estimated habitat availability as the proportion of each habitat type within the study area from satellite images from Global Land Cover Facility (http://glcfapp.glcf.umd.edu), using ArcView 9.3 (ESRI, 2008). Habitat availability (wet season only) was used to calculate the expected number of locations for each habitat type (White and Garrot, 1990) and those were compared with the observed number of locations with a χ^2 goodness of fit test, under the null hypothesis of no selection (Neu, Byers and Peek, 1974; Manly, McDonald and Thomas, 1993). We used the Bonferroni adjustment for our confidence intervals to maintain $\alpha = 0.05$ for analyses by habitat type (Neu, Byers and Peek, 1974).

We captured nine adult snakes. One individual (Aleida) was captured near the end of the wet season, so we only analyzed her data for the dry season. None of the animals lost the transmitter during the study period, or had any ill effect associated to the operation. Mean SVL for females was 1.17 times larger than SVL for males (table 1), but difference was not significant (Mann-Whitney $U = 4$, $P > 0.15$, $n = 9$).

We effectively monitored eight snakes (3M: 5F) during the wet season. The snakes were located four to six times a week for 20 weeks, resulting in a total of 242 locations (not all snakes were found every day). We temporarily lost the signal of three males and two females after three months. Logistic limitation prevented us from looking for all the animals far into the swamp. Therefore, we radio tracked four snakes (all females) for a period of eight weeks during the dry season, completing 255 locations.

Average wet season home range was 25.81 ha (SD = 10.73, MCP at 95%), ranging between 18.4 and 39.4 ha for females and 6.7, and 28.5 ha for males, but did not differ between sexes for either MCP or core areas (MW $U = 3$, $P = 0.180$; and $U = 7$, $P = 0.881$, respectively, table 1). We found no correlation between wet season HR and SVL for our studied snakes ($r = -0.02$, $P > 0.9$, $n = 8$); we did not attempt to test for dry season data, given the small range in HR. Daily and maximum daily and weekly distance movements did not differ between males and females during the wet season (MW $U = 6$, $P = 0.65$; MW $U = 2$, $P = 0.101$; MW $U = 6$, $P = 0.65$, respectively, table 1). Mean dry season HR (MCP at 95%) was less than 1% of that for the wet season and varied between 0.13 and 0.42 ha. The average distance between the dry and wet season center of the HR's core areas was 1.05 km (0.53–1.78 km, $n = 3$, all females).

We expected to find a difference in wet season HR between sexes, because larger animals need larger foraging grounds (Rivas, 2000). Besides of our small sample size, it is likely that the lack of a difference in size between the studied males and females may be the most parsimonious explanation to this result. However, other pressures may affect HR other than just foraging. For instance, males moving around tracking breeding females would increase their HR beyond what is necessary to meet metabolic needs alone (Rivas, 2000). Studies in related taxa also reported similar HR in both sexes in *Epicrates inornatus*, and *Morelia spilota* (Puente-Rolón and Bird-Picó, 2004, Slip and Shine, 1988, respectively).

Mean HR of *E. beniensis* during the wet season in our study is 69% of the mean wet season HR for *E. murinus* in the Venezuelan Llanos (37.4 ha, Rivas, 2000). The larger size of *E. murinus* (average female SVL = 3.70 m in Rivas' study vs. 1.92 m in our sample) may again

Table 1. Standard measurements for Beni Anacondas (*Eunectes beniensis*) studied in the Sirionó territory (Bolivia) and home range (95% Minimum Convex Polygon, and core areas), for both wet, and dry seasons.

	Weight (kg)	SVL (cm)	Tail length (cm)	Wet season						Dry season		
				Home range (ha)	Core area (ha)	Average daily movement	Max 1 day distance movement	Max 1 week distance movement	# of locations	Home range (ha)	Core area (ha)	# of locations
Females												
Martha	11	218	31.5	18.4	0.5	95.6	646.9	1856.8	62	–	–	–
Silvia	7.5	186.2	31.5	35.8	0.1	157.2	300	1589.3	26	0.30	0.01	47
Lizzet	12.75	235.3	36	32.6	14.9	146.7	855.2	1770.7	34	–	–	–
Pamela	6	189.8	31.5	26.2	2.9	248.8	614	1999.9	34	0.13	0.01	55
Diana	3	153.3	26	39.4	1.03	152.1	295.8	855.6	19	0.42	0.11	53
Aleida	4	170	28	–	–	95.6	646.9	1856.8		0.33	0.100	47
Mean	6.4	192.1	30.75	30.5	3.9	160.1	542.4	1614.5		0.29	0.07	51.7
(SD)	(3.76)	(30.2)	(3.44)	(8.31)	(6.24)	(55.41)	(241.58)	(449.50)		(0.148)	(0.055)	(4.16)
Males												
Orlando	6	187.7	31	18.8	1.7	136.8	217	1163.8	25	–	–	–
Jose	3	142.8	31.5	6.7	0.6	110.8	292.3	908.5	24	–	–	–
Carmelo	3.5	159	30	28.5	1.8	193.6	613.7	1919.4	18	–	–	–
Mean	4.16	163.2	30.83	18.01	1.28	147.1	374.3	1330.6		–	–	–
(SD)	(1.61)	(22.7)	(0.76)	(10.92)	(0.62)	(45.01)	(219.25)	(436.19)				
General mean	5.79	182.45	30.77	25.81	2.91	155.2	479.4	1508.0				
(SD)	(3.39)	(30.16)	(2.75)	(10.73)	(4.92)	(48.08)	(231.51)	(464.76)				

Table 2. Habitat use (percentage of locations) by *Eunectes beniensis* at Siriono territory during the wet season. Availability refers to the percentage of each type of habitat in the study area.

Snake	Swamps	Rice fields	Patujusal	Pajatoruno	Bajío	Forest
Martha	1.6	19.4	0.0	58.1	21.0	0.0
Silvia	34.6	19.2	34.6	0.0	0.0	11.5
Lizzet	38.2	5.9	29.4	0.0	26.5	0.0
Pamela	5.9	50.0	5.9	5.9	20.6	11.8
Diana	0.0	26.3	21.1	0.0	52.6	0.0
Orlando	64.0	0.0	0.0	0.0	0.0	36.0
Jose	37.5	0.0	54.2	0.0	4.2	4.2
Carmelo	11.1	11.1	38.9	0.0	22.2	16.7
Mean	24.1	16.5	23.0	8.0	18.4	10.0
Availability	3.8	25.2	8.2	0.3	21.6	40.9

be the simplest explanation for this difference (Rivas, 2000, Pough et al., 2001). Surprisingly, mean dry season HR of Beni anacondas is much smaller than that of Green anacondas (25.1 ha, Rivas, 2000)

Since snakes barely moved during the dry season, we analyzed habitat use only for wet season data. Beni anacondas did not use habitats according to their availability ($\chi^2 = 2,258.5$, $DF = 5$, $P < 0.001$). Snakes tend to avoid both forest, and rice fields, while they use swamps, bajío, and pajatoruno more than expected. However, one snake preferred rice fields (table 2).

The avoidance of forest is not surprising, given that anacondas are highly associated with water and those forests had only small creeks crossing them. All anacondas found in the forest spent the dry season close to a small creek. Rice fields were not frequented by most Beni anacondas, which contrasts with what Green anacondas do in Venezuela, where they often feed on aquatic rats (*Holochilus* sp.; JAR unpublished). However, we noticed that rice fields in the Sirionó territory were devoid of insects (even mosquitoes), probably as a result of the use of pesticides. We strongly believe that rice fields are inadequate for Beni anacondas' conservation. On the other hand, swamps, and patujusal are generally named as the preferred ones for Beni anacondas according to local people and according to our data.

Influence of translocation. Snakes were released between 0.27 to 13.02 km (mean $\pm$ SD $=$ 3.06 $\pm$ 4.17 km) from their capture site. Only one snake returned to her capture site (1.16 km away from the release site). Four snakes established home ranges that included their release sites. Mean distance between release site and the center of the snake's core area was 0.63 km (SD $=$ 0.31). We found no correlation between the distance at which snakes were translocated and HR size ($r_s = 0.21$, $n = 8$, $P = 0.64$), suggesting that most snakes were not moved far away from their HR. All locations during the dry season were in holes, in forested habitats. The maximum distance of holes to a water body was 1,320 m (mean $\pm$ SD $= 128 \pm 596$, $n = 4$).

The main response when snakes are moved to a new area is long distance movements trying to return to their original HR (Kingsbury and Attum, 2009). A translocated *E. murinus* in Venezuela moved > 8 km in a two-weeks period back to where it was caught (JAR unpublished). All our studied individuals, except for one female, remained faithful to their wet season home ranges and did not travel much. This was true even for an individual that was translocated 13.2 km. Thus, the lack of high dispersal by translocated individuals, the proximity of their HR to the capture point, and the overall small HRs exhibited suggest that translocation did not substantially alter the pattern of movement or habitat use of the animals.

Beni anacondas used a much larger home range during the wet season and home ranges during the dry season were extremely small. Studied Beni anacondas preferred shallow swamps, and patujusal over other habitats. We surmise that anacondas avoided forests due the lack of water in these elevated areas. Avoidance of rice fields may be explained because of the relative water low depth and more homogeneous type of vegetation, which probably negatively affected resources, both prey, and cover; rendering rice fields inadequate for the conservation of anacondas in our study area.

Acknowledgements. The study was funded by the Viceministerio de Medio Ambiente, Biodiversidad, Cambios Climáticos y de Gestión y Desarrollo Forestal del Estado Plurinacional de Bolivia, that also granted required permits for research, and by Fundación Amigos de la Naturaleza. We express our gratitude to the Sirionó people, who helped us in the field and captured the snakes for the study. Special thanks go to William Cuellar, President of the Sirionó council. James Aparicio, Adriana Rico, Martha Crump, Xavier Santos, and five anonymous reviewers contributed helpful comments on earlier versions of the manuscript. Fernando Guerra, Fabiola Suárez, Orlando Euriba, and the Cuellar family helped in the field.

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Submitted: May 2, 2017. Final revision received: August 15, 2017. Accepted: September 4, 2017.
Associate Editor: Luca Luiselli.

Appendix. Habitat types, available area for each one at the study site, and their characteristics as considered for the study of Beni anacondas (*Eunectes beniensis*) in Bolivia.

Habitat type	Area (ha)	Representative vegetation species	Vegetation height (m)	Water depth (cm)
Swamps	11.31	*Mikania congesta*, *Ludwigia rigida*, *Cyperus giganteus* and *Heliconia* sp.	1–1.2	15–60
Rice fields	74.45	*Oryza sativa* and *Eichhornia* sp.	0.5–1	15–80
Patujusal	24.39	*Heliconia* sp., and *Cyperus giganteus*	2	20–100
Pajatoruno	0.93	*Cortaderia* sp., and a few *Cecropia* sp. trees	2.5–4	15–30
Bajío	63.82	*Echinochloa* sp., and *Rhynchospora* cf. *trisicata*	1.5	100–110
Forest	121.08	*Attalea phalerata*, *Astrocaryum* sp., *Talisia* sp., *Triplaris boliviana*, *Heliconia* sp. and several unidentified lianas.	>4	0–80