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Home range and habitat use of *Basiliscus plumifrons* (Squamata: Corytophanidae) in an active Costa Rican cacao farm

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Abstract. The home range, habitat use, and distance from water sources were estimated for *Basiliscus plumifrons* in an agricultural matrix in Costa Rica. Using radio telemetry, four females and four males were studied from July-September (2004) in a cocoa (*Theobroma cacao*) farm embedded in landscape dominated by banana and pineapple plantations. Females occupied a home range that averaged 1877 ± 1052 m^2 ($n = 4$); male home ranges were similar, averaging 1740 ± 1288 m^2 ($n = 4$; t-test $= -0.12$, $P = 0.90$). Cacao with a limited shade canopy was the predominant habitat available and used most frequently when compared to other habitats ($\chi^2 = 116.67$; $P < 0.0001$). *Basiliscus plumifrons* remained close to water although individuals occasionally traveled up to 80 m from water. However, both males (24.30 ± 1.93, $n = 133$) and females (26.82 ± 1.97, $n = 128$) maintained similar average distances from water resources (Kruskal-Wallis, $H = 1.57$, $P = 0.20$). Agroforestry systems connected to patches of riparian forest probably play an important role in the ecology and conservation of *B. plumifrons*.

Key words: *Basiliscus plumifrons*; cacao plantation; home range.

Introduction

Cacao (*Theobroma cacao*) is a tree crop of the humid lowland tropics managed primarily by small farmers. When cacao farms maintain a canopy of shade trees, they tend to support greater levels of biodiversity then most other tropical crops (Rice and Greenberg, 2000). Vegetation structure in shaded cacao often has multiple strata and high tree species diversity (Suatunce, 2002; Rice and Greenberg, 2000; Greenberg et al., 2000). Cacao plantations have been documented to support high

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species diversity for insects (Klein et al., 2002; Suatunce, 2002; Perfecto et al., 1996; Room, 1971; Leston, 1970), birds (Reitsma et al., 2001; Greenberg et al., 2000), and mammals (Guiracocha, 2000). However, the few reports on reptiles are limited to surveys (Fauth et al., 1989; Heinen, 1992; Lieberman, 1986). We were interested in learning how *Basiliscus plumifrons* might exploit a perennial cacao agroecosystem in an otherwise heavily modified landscape. Studying the behavior of *B. plumifrons* in such a habitat is potentially important for determining its future in rapidly changing environments, and whether cacao can provide a refuge in a landscape dominated by monoculture plantations.

Despite their wide geographic distribution, spectacular appearance, water-walking capabilities, and a presence in many habitats on the Neotropical mainland, our knowledge of the ecology of corytophanid lizards (*Basiliscus*, *Corytophanes*, *Laemanctus*) is quite limited. Species of *Basiliscus* are especially conspicuous in some habitats and, aside from work by Hirth (1963a) and Van Devender (1978, 1982), they have been largely ignored by lizard ecologists. *Basiliscus plumifrons* is, arguably, the most spectacular member of the genus and, aside from a short-term telemetry project by Sajdak et al. (1980), our knowledge of the ecology of this lizard is largely anecdotal.

Basiliscus plumifrons is a large (snout-vent length [SVL] to 250 mm in males and 174 mm in females), moderately common lizard that occurs in the humid lowlands on the Atlantic versant from eastern Honduras to western Panama and on the Pacific slope in southwestern Costa Rica (and probably adjacent Panama) (Savage, 2002). It is largely arboreal, diurnally active, and catholic in diet, consuming vegetation, invertebrates, and an occasional vertebrate (Savage, 2002). Of the three species of *Basiliscus* that occur in Costa Rica (*B. basiliscus*, *B. plumifrons*, and *B. vittatus*), only *B. plumifrons* is found on both versants. Despite its conspicuous presence in some habitats, few field studies exist (Hirth, 1963b, Sajdak et al., 1980), and no quantitative assessment of any aspect of its ecology has been undertaken. Movements and habitat use by mobile animals are necessary to delineate sound conservation and management strategies for species that exploit human-modified habitats (Johnson, 2000).

We used radio telemetry to determine home range sizes and habitat use of *B. plumifrons* within an active cacao farm in Costa Rica. Based on this information, the importance of cacao vegetation structure for the species is discussed.

Materials and Methods

Study site

This study was carried out in the Guapiles region, near the village of Pueblo Nuevo de Villa Franca, La Rita District, Limon Province, Costa Rica (10°20′N, 83°20′W). The region occurs in the Premontane Wet Forest life zone at approximately 100 m elevation. The study site was a relatively small (120 ha) organic cacao farm surrounded by pastures with scattered trees (northeast), a banana plantation (west), pineapple fields (east), and abandoned secondary forest with some pasture and annual crops (southeast).

The farm is approximately 30 years old with cacao trees maintained at a height of less than four meters, with grassy undergrowth and abundant cacao litter in shaded areas. The farm is bisected by several streams and water channels that function as a biological corridor for animals by connecting different habitats to the northeast and southeast (secondary forests, riparian forests and pastures with scattered trees).

The cacao trees are evenly spaced on a 4.0 m $\times$ 4.0 m grid with a central road and a cable system for transporting cacao pods and compost for fertilizer. The open understory facilitated observation and mapping habitat use by basilisks. *Basiliscus plumifrons* was observed diurnally when it was active on the ground and in trees within the cultivated areas and in trees and shrubs at the periphery of the cacao.

Capture and radio telemetry

We captured lizards within the cacao by noosing them with a nylon cord attached to a 2.0 m metal pole. All captures were at night when the animals were inactive. Lizards were released at their capture sites following data collection that included: capture hour, site, perch height, perch diameter, perch type, perch species, perch diameter at breast height (when applicable), activity, GPS coordinates, distance between lizard and water sources, and animal orientation.

All animals were sexed and measured and only presumed adults were used for telemetry work (radio-marked males had SVLs of 193-197 mm, and females had SVLs of 152-170 mm). Radio transmitters (PD-2 Holohil System Ltd, Carp, Ontario, Canada KOA 1LO) were attached to two lizards (a male and female) on 7 April using a modified nylon fishing-line “harness” (Knapp and Owens, 2005). They were tracked for two weeks to ensure proper radio attachment protocol. Six more radio transmitters were attached to three adult females and three adult males in early July, after we concluded that harnesses caused no harm to the lizards. Battery life for the transmitters ranged from 3.5 to 6 months. Five males and seven females were included in the study because three females and one male lost their radios. Data were collected between July and September 2004, which coincided with the short dry season.

We used a tracking system that permitted independent radio telemetry locations (White and Garrott, 1990). To locate each animal with a radio, we used portable Yagi RA-2AHS antennas and TR-4 receivers (Telonics, Mesa, Arizona) until we had a visual observation. Then we used a Garmin 12L GPS device to determine the exact location of the study individual. Lizards were sampled daily at a different hour during 13 days per month. For example, the first animal was sampled at 0600 h on day 1, at 0700 h on day 2, at 0800 h on day 3 and successively until 1800 h, so each animal was located at different hours during the day. Each lizard was observed for 5 min at 5-min intervals between each observation; this was repeated four times.

Analysis

Home range. We calculated the home range sizes of *B. plumifrons* using the minimum convex polygon method for data collected during the study period (July-September 2004) (Mohr, 1947). We used all individual observations except for GPS data points that did not give an exact location of the capture site. These data were analyzed using the ArcView 3.3 Program (Environmental Systems Research Institute, Inc., Redlands, California) and use of "animal movement" extension and home range. The means of home range sizes were compared between sexes using a t-test (Zar, 1996) and estimating significant differences at the $P < 0.05$. Overlap areas were also calculated between individuals. If fewer than 10 data points were collected for any lizard, its data were not included in the home range analyses.

Habitat use. Habitat types were delineated using an image obtained from the Project Mission (National Program for Research in Airtransport and Remote Sensing) and geo-referencing Lambert north. Each cover type was then defined based on ground observations. To determine lizard habitat use, all locations were plotted on a habitat map made using GIS locations. Habitat types were categorized into six classes: a) riparian forest: vegetation formation around water courses, b) cacao with shade trees: vegetative formation inside a cacao plantation with diverse shade tree species, c) cacao with riparian forest: vegetation near borders of canals and streams, d) cacao without emerging trees, e) roads and f) facilities and dwellings. The number of expected locations for each lizard per habitat type was calculated by multiplying the total number of observed locations for each lizard by the percentage of each habitat in its home range. Later, the expected number of locations was compared to the total number of observed locations in the habitat types using Neu's goodness of fit test with Biotas software (version 1.03.1 Alpha, Ecological Software Solution) (Neu et al., 1974; White and Garrott, 1990).

Distance from water. We analyzed the distances of lizards from water sources using waypoints captured using radio telemetry. The Spider analysis with the animal extension SA v2.04 beta (www.esri.com) estimated the distance from the water resource. The water resource was identified using a 2005 satellite image.

Alpha level for significance = 0.05, and all means are presented ± SE.

Results

Home range sizes

A total of 238 data points was registered from four males ($n = 127$) and seven females ($n = 111$). Although mean female home range size (1877 ± 1052 m^2, $n = 4$) was greater then mean male home range size (1740 ± 1288 m^2, $n = 4$), the difference was not significant (t-test $= -0.12$, $P = 0.90$) (table 1). Males used

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Table 1. Home ranges of *Basiliscus plumifrons* (July-September 2004).

Radio collar	Sex	m^2	Ha	Perimeter	Points used	Tree species used
62	Female	367	0.04	0.037	23	10
70	Female	4964	0.50	288.54	26	5
74	Female	1432	0.14	143.76	44	6
78	Female	747	0.08	127.87	18	2
60	Male	555	0.06	107.84	39	4
66	Male	5603	0.56	408.78	31	15
82	Male	406	0.04	79.76	27	2
84	Male	397	0.04	79.88	30	16

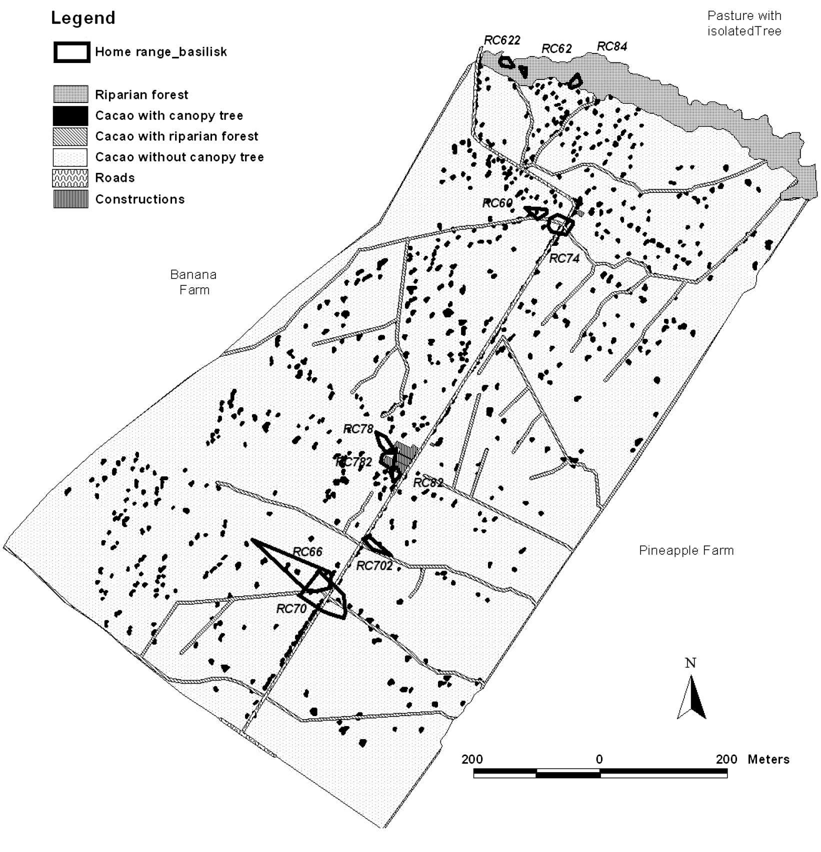

Figure 1. Home range of *Basiliscus plumifrons* estimated using the minimum convex polygon.

between 2-16 plant species, whereas females used 2-10 species. The numbers of tree species used by females ($r = 0.20$, $P = 0.73$) and males ($r = 0.20$, $P = 0.72$) was not correlated with home range sizes (table 1).

The two largest home ranges (female #70 and male #66) overlapped (fig. 1). This overlap area was 2-3 times greater than the home ranges of any other lizards.

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Habitat use

Cacao without canopy trees was the predominant habitat available and used most frequently when compared to other habitats ($\chi^2 = 116.67$; $P < 0.0001$). However, habitats such as cacao with canopy trees or riparian forest also represented an important resource. The lizards' use of buildings, such as storage areas and the processing plant, would have allowed *B. plumifrons* to diversify resource use, but such use was not the case ($n = 8$ observations) (table 2).

Both sexes used cacao habitat without canopy trees and riparian forest more than expected. Overall, for both males ($\chi^2 = 82.73$; $P < 0.0001$) and females ($\chi^2 = 56.80$; $P < 0.0001$), observed habitat use was significantly different than expected habitat use (table 3).

Distance from water

Basiliscus plumifrons seldom moved more than 5-10 m (30%) and 15-25 m (17%) from water, but occasionally traveled up to 80 m from water. Both males (24.30 ± 1.93, $n = 133$) and females (26.82 ± 1.97, $n = 128$) maintained a similar average distance from water (Kruskal-Wallis, $H = 1.57$, $P = 0.20$). For males, distribution relative to water was between 0-20 m and 52-58 m (fig. 2). Females maintained a more uniform distribution in space and were most commonly found between 0-10 m (30%) and 10-21 m (23%) from water. Both males and females

Table 2. Habitat availability and number of tree species used in each habitat category by *Basiliscus plumifrons* in an organic cacao farm.

Habitat	Observed count	Habitat proportion	Expected use	Selection ratio	Tree species used
Riparian forest	47	0.03	9	0.006	18
Cacao without canopy trees	176	0.90	231	0.615	12
Roads	5	0.01	2	0.000	3
Cacao with canopy trees	7	0.02	4	0.000	2
Cacao with riparian forest	14	0.04	11	0.002	6
Buildings	8	0.00	0	0.000	–

Table 3. Availability of habitat found for *Basiliscus plumifrons* by sex in the organic cacao farm.

Habitat	Observed count		Proportion of landscape	Expected use
	Male	Female		
Riparian forest	26	21	0.034	4
Cacao without canopy trees	87	89	0.898	116
Cacao with canopy trees	2	5	0.016	2
Cacao with riparian cover	6	8	0.042	5
Roads	0	5	0.009	1
Buildings	8	0	0.002	0

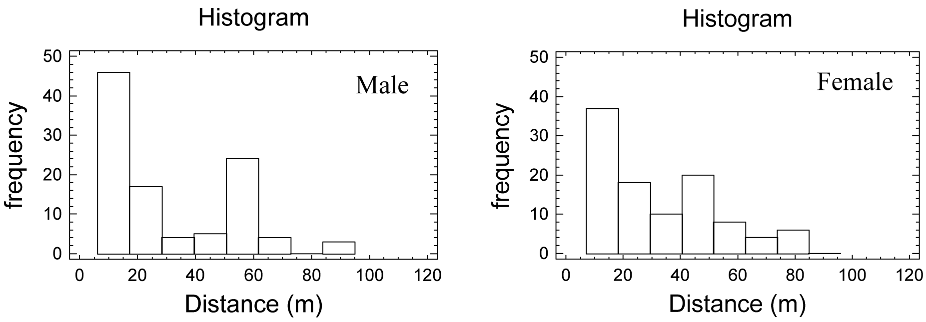

Figure 2. Number of sightings of *Basiliscus plumifrons*, with respect to distance from water at Finmac.

had a second observation peak with distances between 42-63 m, but observations of lizards >80 m from water were rare ($n < 5$).

Discussion

Home range

Home range is defined as the area traversed during the natural activities of food gathering and mating (Burt, 1943). Lizards were seen foraging during this period, but neither mating nor visible overt territorial defense were observed. Home range sizes for male and female *B. plumifrons* did not differ statistically, but one male had a home range 15 times larger than some females, and one female had a home range many times larger than some males (table 1). Sajdak et al. (1980) studied three *B. plumifrons* (two males and a female) in Costa Rica with radio-telemetry for 10 days and estimated home ranges of 316-1006 m^2 with core activity areas between 57-114 m^2; females had slightly smaller home ranges than males. We are unsure why so much variation occurs within sexes.

Wone and Beauchamp (2003) studied 69 individuals of a horned lizard (*Phrynosoma mcallii*) in the Colorado Desert in California for nine months. They determined that home ranges varied by a factor of 90 (651-59,237 m^2), much more than in the present study. They also documented considerable overlap in home ranges. Haenel et al. (2003) studied home ranges of eastern fence lizards (*Sceloporus undulatus*) in New Jersey and found home range sizes to be correlated with body size in adult males, and males sharing home ranges with other males. The number and location of females with which males interacted determined size and shape of male home ranges. In the present study, too few animals were followed to draw conclusions about that aspect of lizard behavior.

Habitat use and distance from water

Arboreal lizards use trees for foraging, nesting, resting, and refuges (Reaney and Whiting, 2003). Hirth (1963) found adult *B. plumifrons* close to riverbanks and noted a preference for riparian habitats. As expected, at our study site cacao without shade trees was used extensively by the lizards, as was riparian forest. Likewise, the lack of sightings in areas where lizards might be particularly vulnerable to predation (e.g., on roads or open areas away from water) was expected. *Basiliscus plumifrons* is scansorial and used arboreal habitats to elude predators (e.g. humans) and, presumably, to observe the landscape.

Basilisks are one of few vertebrates capable of running across open water to avoid predators, and they obtain food along the borders of streams (Hsieh and Lauder, 2004). Rivers and streams in our study area swelled with heavy rains and, upon returning to normal size, left areas with fresh mud where basilisks searched for food, especially insects in organic detritus (G. Herrera, pers. observation).

At Finmac, both males and females maintained similar distances from streams and creeks. Much of their time was spent in trees and shrubs, such as *Zygia longifolia, Hamelia patens, Ochroma piramidale, Erytrina poeppigiana, Leucaena leucocephala* and cacao trees that functioned as refuges and resting sites. However, not all food is found near water sources. Lizards occasionally dispersed to non-aquatic sites while using trees such as *Theobroma cacao, Ochroma piramidale, Cecropia insignis* and *C. obtucifolia* where food, resting sites, and, likely, other resources, were also available, thereby increasing home range size.

Relation to conservation in cacao agroecosystems

We found *B. plumifrons* to be common in cacao ecosystems (C. Vaughan, unpubl. data), especially along riparian zones and drainage canals. As an insectivore, it may perform a valuable role in controlling damaging insects to cacao, and the presence of water favors its presence. Cacao seems a valuable habitat for *B. plumifrons* because of its combination of habitat components (water sources, shade, and structure). Cacao farms and riparian forests permit the adults and juveniles to easily hide from predators. Whether these resources remain *in situ* and are managed or modified will affect *B. plumifrons* populations. Our data suggest that the habitat used by *B. plumifrons* is only a small part of what these animals can potentially use. Agroforestry systems connected to patches of riparian forests appear to play an important role in this species' conservation.

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