CNEMIDOPHORUS LEMNISCATUS (SQUAMATA: TEIIDAE) ON CAYO COCHINO PEQUEÑO, HONDURAS: EXTENT OF ISLAND OCCUPANCY, NATURAL HISTORY, AND CONSERVATION STATUS

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Abstract.—Cayo Cochino Pequeño (CCP) is a western Caribbean island with a surface area of only 0.64 km² in the Cayos Cochinos Archipelago, Department of Islas de la Bahía, Honduras. It is relatively ecologically complex, with high herpetofaunal diversity (one turtle, six snake, eight lizard, and one amphibian species), considering the size and location. Although not the largest island in the archipelago, it alone is inhabited by the widely distributed neotropical lizard *Cnemidophorus lemniscatus* (Rainbow Whiptail: Teiidae). Herein, we describe occupancy of *C. lemniscatus* on CCP, which uses a fraction of the ca. 7% of flat sandy terrain where the species would be expected. Over 90% of individuals of *C. lemniscatus* observed were on the southern part of the island in the East Beach windward zone. The remaining observations on *C. lemniscatus* were made at two newly discovered leeward beach sites, a leeward beach site from which it was reported in 1993, and the first inland forest site reported for this lizard. Most of the habitat used by *C. lemniscatus* on CCP is within 10 m of the high tide line, which exposes it to being over-washed by periodic storm surges (e.g., Hurricane Mitch in 1998). Use of open beach and fringing beach strand vegetation by the species is primarily associated with reproductive and foraging activities. We used 25 of these lizards collected from CCP in 2005 and 2006 for preliminary analyses of diet and reproductive characteristics. Adult males averaged 67.7 ± 1.69 mm SVL and 7.6 ± 0.50 g mass; adult females averaged 63.6 ± 1.60 mm SVL and 6.0 ± 0.50 g mass. The SVL and clutch ranges of seven gravid females of *C. lemniscatus* from CCP were 57–67 mm and 1–2 eggs, respectively. Reproductive potential in this insular Caribbean population of *C. lemniscatus* is likely increased by an extended activity period, which allows for rapid maturation and multiple clutches per year, as reported for the species in other parts of its range. The diet of *C. lemniscatus* on CCP includes amphipods, arachnids, insects, and plant parts. The density of the species in parts of the island indicates that the population is successful under present conditions; however, the small areas of suitable habitat obviously make it susceptible to extirpation by both human and natural perturbations.

Key Words: Cayo Cochino Pequeño; *Cnemidophorus lemniscatus*; Honduras; natural history; Rainbow Whiptail

INTRODUCTION

Between 2004 and 2007, CEM, SMB, and SEWG worked for extended periods on Cayo Cochino Pequeño (CCP), Cayos Cochinos Archipelago, Department of Islas de la Bahía, Honduras, during a collaborative study of the ecology and conservation status of the resident population of the widely distributed Boa Constrictor (*Boa constrictor*). In a part of the dry season in July and August 2004 and subsequently, they helped deploy and utilize drift fences, pitfall traps, and separate observational transects to observe and capture *B. constrictor*. Incidental to this objective, individuals of *Cnemidophorus lemniscatus* (Rainbow Whiptail: Family Teiidae), a diurnal and actively-foraging terrestrial lizard, were also observed, captured, and released. At

that time, the population had been known from only one specimen reported from the northern leeward tip of CCP by Wilson and Cruz-Diaz (1993). Consequently, we initiated a study of *C. lemniscatus* on what is arguably the smallest island within its range. Elsewhere in Central America the few observations on the natural history of *C. lemniscatus* mainly have come from small areas of the Atlantic coastal strand (Sexton et al. 1964; Echternacht 1968; Sunyer et al. 2009), together with one report of reproduction in the species on Isla de Utila, Honduras (Gutsche 2005). The biology of the *C. lemniscatus* species complex has been more thoroughly studied within the much more extensive coastal and inland distribution area in South America and nearby islands for distribution (Peters and Donoso-Barros 1970; Hoogmoed 1973; Serena, 1985), systematics (Cole and
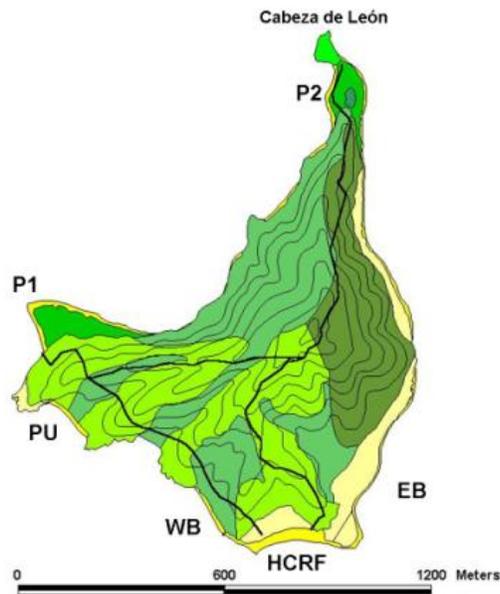
FIGURE 1. Map of Cayo Cochino Pequeño, Cayos Cochinos Archipelago, Department of Islas de la Bahía, Honduras, showing the locations of the Honduran Coral Reef Foundation compound (HCRF), major beaches (EB, East Beach; WB, West Beach; PU, Playa Uva; P1, Playa 1; P2, Playa 2), Cabeza de León (Lion's Head Promontory = Bonkes Nose Point), trail system, and elevation contours. (Prepared by Honduran Coral Reef Foundation staff)

Dessauer 1993; Markezich et al. 1997; Ugueto et al. 2009), and ecology (Serena 1984; Vitt et al. 1997; Mesquita and Colli 2003; Mojica et al. 2003). It is known to be abundant, though it remains essentially unstudied, on several regional Caribbean islands (e.g., Roatán, Honduras [Wilson and Hahn 1973]; San Andrés, Catalina, and Providentia, Colombia [Dunn and Saxe 1950]), in addition to CCP and Utila.

Preliminary information on habitat utilization, body size, and color pattern of *C. lemniscatus* on CCP was published by Montgomery et al. (2007). Although the East Beach area on the southern windward side of the island continues to be the largest known area of occupancy of *C. lemniscatus* on CCP, we report new observations for the species for that area, as well as for two newly discovered leeward beach sites, a rediscovered leeward beach site where the first specimen was collected by others in 1988, and one inland forest site. We also report newly obtained descriptive information on behavior and conservation status, data for diet, variation in body size, and reproductive characteristics for *C. lemniscatus* on CCP.

MATERIALS AND METHODS

The island.—Cayo Cochino Pequeño is the second largest emergent land mass at 0.64 km^2 in the western Caribbean Cayos Cochinos Archipelago (15°58'18.99"N, 86 ^{o} 28'31.34"W) located about 14.8 km north of mainland Honduras. The ecological complexity of the island is enhanced by three sets of attributes: non-uniform shape (large ratio of shoreline to area); rock base (positional stability); and steep slope from sea level to 141 m (high surface area and habitat diversity; Fig.1). No fewer than five major habitat assemblages have been delineated for CCP: sea-wind scrub; mangrove forest; palm forest; hill forest; and rocky promontory (Wilson and Cruz-Diáz 1993; Bermingham et al. 1998; McCranie et al. 2005). Herpetofaunal diversity here is surprisingly high (one turtle, six snake, eight lizard, and one amphibian species) considering the small size and location of CCP (Wilson and Cruz-Diáz 1993; Bermingham et al. 1998; McCranie et al. 2005). Recent natural ecological impacts on this privately owned continental island have included Hurricane Mitch in October 1998 and palm tree deaths from lethal yellowing disease. Ongoing human activities that impact CCP include selective logging, poaching *Boa constrictor* and *Ctenosaura melanosterna* (Honduran Paleate Spiny-tailed Iguana), development of the Honduran Coral Reef Foundation (HCRF) field station, maintenance of a grass helicopter landing pad, production of a reality television show, and trail clearing (Wilson and Cruz-Diaz 1997; Bermingham et al. 1998; McCranie et al. 2005; Montgomery et al. 2007).
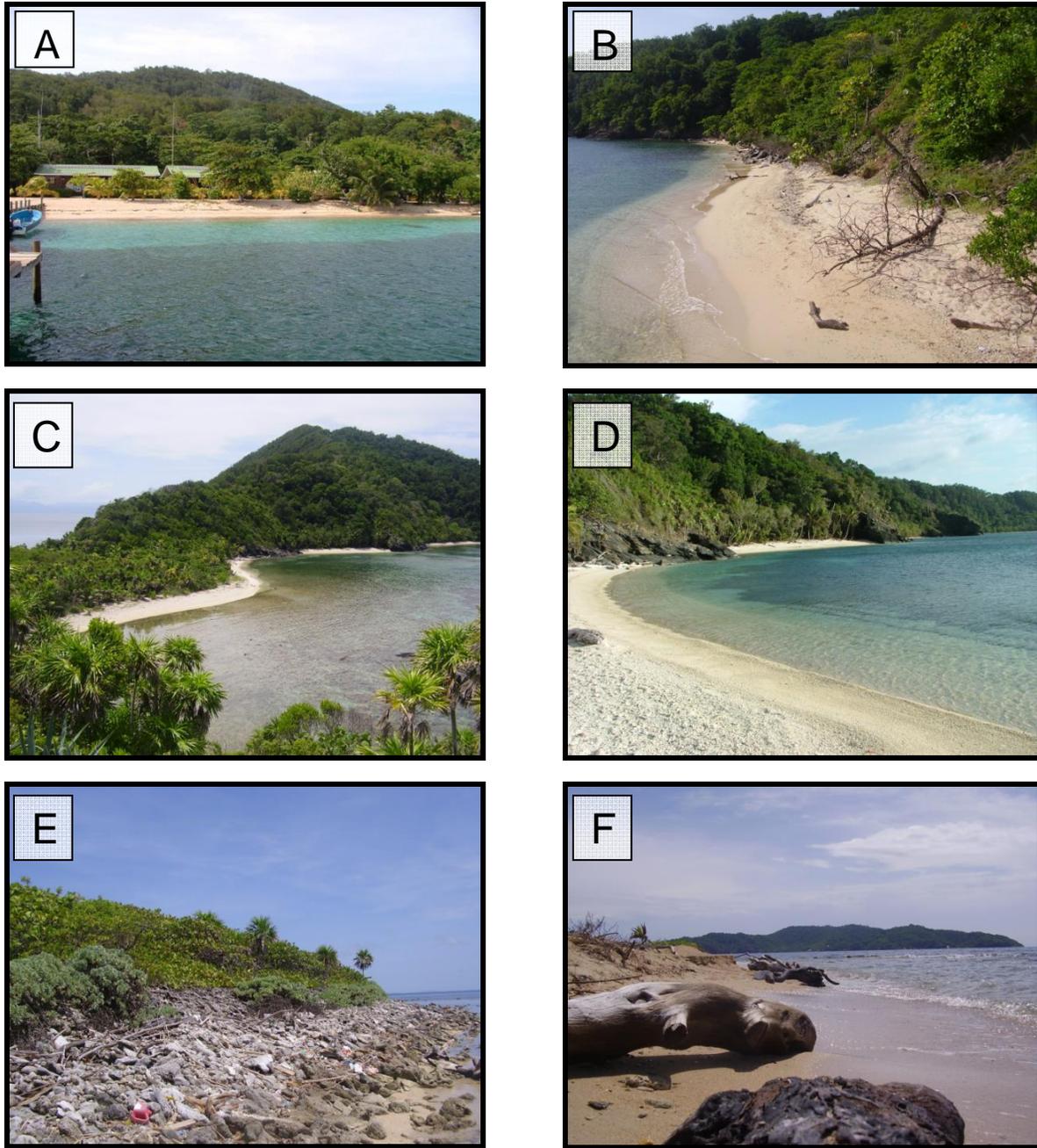
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FIGURE 2. A: Looking inland at the open area near a building of the Honduran Coral Reef Foundation compound on Cayo Cochino Pequeño, Cochinos Archipelago, Department of Islas de la Bahía, Honduras, in which males of *Cnemidophorus lemniscatus* were initially observed in 2006. B: Looking at the abrupt northern boundary of leeward West Beach where *C. lemniscatus* was observed in 2005 and 2006 on Cayo Cochino Pequeño, marked by the steeply sloped forest to the tide line. C: Looking south from the Lion's Head Promontory on Cayo Cochino Pequeño at the beach components fronting a coconut grove at Playa 2 on the leeward side of the northern isthmus, at the apparent site of the discovery of *C. lemniscatus* by L. D. Wilson and G. A. Cruz-Diaz in 1988, and rediscovered in 2005 during this study. D: Looking at a near view of the leeward beach used by *C. lemniscatus* at Playa 2 on Cayo Cochino Pequeño, facing south. E: Looking at the rocky windward east side of the isthmus to the Lion's Head Promontory at the northern tip of Cayo Cochino Pequeño, which is apparently unsuitable for colonization by *C. lemniscatus*. F: Examples of drifted logs on windward East Beach on Cayo Cochino Pequeño used by *C. lemniscatus* for foraging and basking; in the background is the sky line of nearby Cayo Cochino Grande, Honduras. (All photographed by Scott M. Boback)

Nevertheless, the effects of these occurrences on the aforementioned habitat assemblages have been moderated by the existence of a management plan for the area, developed by the HCRF staff in conjunction with World Wildlife Fund (McCranie et al. 2005; Montgomery et al. 2007).

Taxonomic considerations.—We use the binomial *Cnemidophorus lemniscatus* for the teiid lizard population on CCP as a provisional designation pending assessment of the taxonomic contents of *Cnemidophorus* (see Reeder et al. 2002), and evaluation of the status of *C. lemniscatus ruatanus* Barbour, 1928 (see Wright 1993), type locality Isla de Roatán, Honduras. Consequently, the CCP population is by default relegated to the nominal subspecies *C. lemniscatus lemniscatus*, presently a "catchall" for populations requiring taxonomic evaluation in South America (e.g., in French Guiana, Suriname, Guyana, Brazil, Venezuela, and Colombia), Central America (Panama, Nicaragua, Honduras, and Guatemala), and on over a dozen islands in the Caribbean Sea (Burt 1931; Peters and Donoso-Barros 1970; Cole and Dessauer 1993; Markezich et al. 1997; Sunyer et al. 2009).

Study sites.—We searched all sandy beaches and the trail system on CCP for the presence of *C. lemniscatus* (Fig. 1, map; Fig. 2, island habitats; Fig. 3, dorsal color pattern). We refer to the beaches as EB (East Beach), WB (West Beach), PU (Playa Uva), P1 (Playa 1), and P2 (Playa 2). The terms "East Beach" and "West Beach" are our designations and are not indicated on any official

map; the other beaches are identified according to recent maps of the island. Weather data collected at the HCRF field station indicate that daily air temperature fluctuates from ca. 25º C to ca. 30º C (e.g., the lows and highs generally occur during the rainy and dry seasons, respectively). A few annual seasonal cold fronts may drop local temperatures to < 25º C for several days. The rainy season extends from October (< 500 mm) to February (400 mm), with a peak in rainfall in November (825 mm). The dry season extends from May to September, with the lowest rainfall in July (< 100 mm). The shift from rainy season to dry season for CCP is paralleled by a decline in relative humidity from approximately 92% to less than 80%. Prevailing winds blow from northeast to southwest over the north-south axis of the island.

Collections, field identifications, and data.—We made field observations on *C. lemniscatus* on CCP during 2004 (July and August), 2005 (July, August, and September), 2006 (May, June, July, August, September, and December), and 2007 (June, July, and August). We weighed (± 0.01 g by an electronic balance), measured (± 0.1 mm by a caliper; LSVL = live and/or pre-preserved snout-vent length; LTL = live and/or pre-preserved tail length; PSVL = post-preserved snout-vent length [i.e., SVL unless otherwise noted]), and determined the sex of all captured lizards, including both those released and retained as vouchers (Appendix 1). Male lizards were identified by the presence of hemipenal bulges at the base of the tail, everted hemipenes, and/or a large pointed paracloacal scale
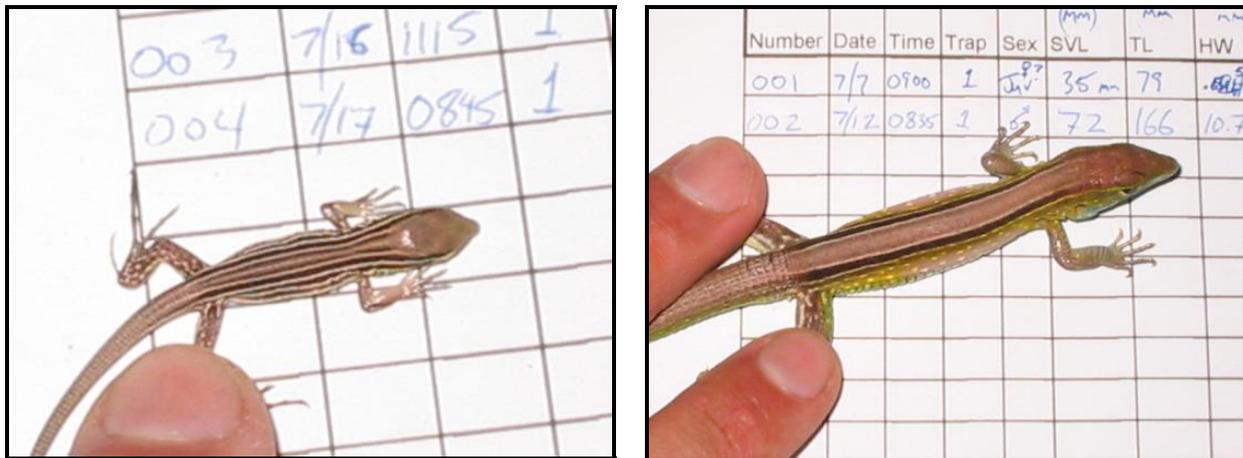

FIGURE 3. Left: Live juvenile (released) of *Cnemidophorus lemniscatus* captured in the winward East Beach area on Cayo Cochino Pequeño, Honduras (note dorsal pattern of nine pale-colored stripes). Right: Live adult male (released) of *Cnemidophorus lemniscatus* captured in the East Beach area on Cayo Cochino Pequeño (note that the lower and upper lateral stripes on each side have been replaced by spots). (Both photographed by Scott M. Boback)

(= anal spur) anterio-lateral to each side of the vent (Burt 1931; Markezich et al. 1997). For the CCP population, we classified females, which lacked enlarged paracloacal scales, as adults if they were $\geq$ 57 mm SVL, which was the size of the smallest gravid female examined (see below). We classified males from the island as adults if they were $\geq$ 55 mm SVL, the size of the smallest male examined with hypertrophied testes. We used lizards of 50 mm or larger in comparisons of regional populations of *C. lemniscatus* to account for possible differences in size at maturity (Mesquita and Colli 2003; Mojica et al. 2003).

In 2004 and 2007 we released all 14 of the *C. lemniscatus* captured on CCP. We collected and preserved 20 specimens of *C. lemniscatus* from the island in 2005 and five in 2006. Live lizards not retained for voucher specimens were released at the site of capture within 24 hours. We collected lizards for preservation by hand, blowgun, and/or rubber band. They were fixed in 10% formalin, stored in 70% ethanol, legally exported to the USA, and deposited in the University of Arkansas collection (UADZ 8221–8245). All voucher specimens we collected were from the East Beach area of CCP. Therefore, all newly discovered and rediscovered sites of occurrence for *C. lemniscatus* on CCP were based on sight identifications and/or photographs of lizards, rather than voucher specimens. The distinctive color pattern of *C. lemniscatus* provided a reliable means of identifying lizards that were not collected (Fig. 3). We also present data based on specimens of *C. lemniscatus* from the following collections: University of Kansas Natural History Museum (KU); Florida Museum of Natural History (FLMNH); Auburn Natural History Museum (AUM); and Brian P. Butterfield collection (BPB).

Treatment of data.—We used a t-test and ANCOVA to test for sexual size dimorphism in adult lizards from CCP and other populations of *C. lemniscatus*. We also used ANOVA to compare body size among the CCP specimens and those from the aforementioned museums (Appendix 2). All means are reported ± 1 SE. Statistics related to body size and reproductive characteristics (e.g., clutch size and egg dimensions) were performed using JMP 7.0 (SAS Institute Inc., Cary, North Carolina, USA). However, all statistics on diet were analyzed using Systat 11.0 (Systat 2004). We set α at 0.05 for all statistical tests.

Analysis of lizard stomach contents.—We checked for stomach contents in 21 of 25 specimens of *C. lemniscatus* collected from CCP in 2005 and 2006 for analysis of seasonal food habits. We placed the material removed from each of 19 lizard stomachs with contents in separate vials of 70% ethanol and sent them to MAP

for identification to the lowest taxonomic level possible, which was usually to family. We measured prey items and plant material to the nearest 0.1 mm in length and width. We used length and width data to estimate the volume of each prey item using the equation: $V = 4/3\ \pi\ (1/2\ \text{length})(1/2\ \text{width})^2$ (Vitt et al. 1993). Diet breadth for the sample was calculated using the equation: $B = 1/\sum p_i^2$ where p_i is the proportion of prey type i in the diet. We made separate diet breadth calculations for each prey type (Numeric Diet Breadth) and prey volume (Volumetric Diet Breadth) to compute p_i. We used a Pearson correlation coefficient ($\alpha = 0.05$) to quantify the relationship between preserved lizard SVL and total volume of prey per lizard stomach for all data pooled.

Reproductive characteristics.—Reproductive females of *C. lemniscatus* were those with either yolked ovarian follicles of > 2.5 mm in diameter or oviductal eggs (Mojica et al. 2003; Walker and Rhoads 2003). We determined means for potential clutch size, ovarian follicle size, and oviductal egg size from seven preserved *C. lemniscatus* from CCP, comparative material of the species from mainland Honduras, Panama, and an introduced population in Florida (Butterfield et al. 2009; Appendix 3). For each reproductive female, we measured a single, representative oviductal egg or ovarian follicle to the nearest 0.5 mm. We compared oviductal egg and ovarian follicle size among populations using ANOVA. We tested the relationship of clutch size and egg size to female SVL using least squares regression (LSR; $\alpha = 0.05$).

RESULTS

Island occupancy.—Our assessment of the conservation status of *C. lemniscatus* on CCP necessitated mapping the extent of its colonization on the island and understanding threats to its continued success in those enclaves. It is noteworthy that we did not observe *C. lemniscatus* in the vicinity of the HCRF compound on the southern tip of CCP in 2004–2005 (Figs. 1 and 2A; Table 1); however, we observed three adult males (sex determined by color patterns of spotted sides and blue-green faces and throats) there in 2006. Lizards were active at various times of day within parts of the ca. 600 m^2 HCRF compound ca. 30 m from the high tide line in an area limited for lizards by shade from buildings and the thick forest canopy farther inland. On the beach side of the buildings, the substrate of sand/coral fragments supports little vegetation except for landscape plantings and a few coconut palms. Lizard activities included foraging on the open sand, movements in and out of landscape plants, and sorties under and away from buildings (stilted to one meter

TABLE 1. Variation among the five sites on Cayo Cochino Pequeño, Cayos Cochinos Archipelago, Department of Islas de la Bahía, Honduras, currently inhabited by *Cnemidophorus lemniscatus*. L = location; H = habitat description; N = ~ number lizards present; R = risk of population to extirpation or other negative impacts.

Site 1	L: Honduran Coral Reef Foundation compound on the southern tip (ca. 600 m^2 and 30 m from high tide line)
	H: Largely un-vegetated sand/coral fragments around buildings and landscape plantings
	N: Three males observed in 2006; likely presence of immigrants from East and /or West beaches
	R: High susceptibility to human activities and/or lack of deme of minimal breeding size
Site 2	L: West Beach on southern leeward side of island
	H: Strip of sand/coral fragments 3-10 m wide from near tide line to forest edge
	N: Two lizards observed in 2005 and two in 2006; likely only a few dozen lizards present
	R: High susceptibility to hurricane over-washing
Site 3	L: Playa 2 on northern leeward side of island near Lion's Head Promontory
	H: Beach of sand, coral fragments, and fine flotsam 2-8 m wide from tide line to palm forest
	N: Few dozen individuals present extrapolating from available habitat and lizards observed
	R: High susceptibility to hurricane over-washing
Site 4	L: East Beach on southern windward side of island (ca. 60 x 400 m)
	H: Beach of sand/coral fragments with large flotsam to sea-wind scrub to palm forest
	N: Source of over 90% of lizards of the species observed on the island
	R: High susceptibility to hurricane over-washing of all except the palm forest
Site 5	L: Upland forest ca. 250 m from East Beach
	H: Compacted soil and rocks with forest litter except for trail
	N: Only occasional immigrant Rainbow Whiptail expected within the forest
	R: High susceptibility based on natural habitat limitation

above ground level to mitigate the effects of storm surges). Presence of *C. lemniscatus* within the highly human-modified HCRF environs on CCP is consistent with observations of its use of anthropogenic habitats elsewhere within its geographic range. However, continued use of the compound by *C. lemniscatus* would likely be on an incidental basis. The East and West Beach colonies of *C. lemniscatus* are possible sources for the lizards observed at the HCRF site in 2006 (Fig. 1).

Presence of *C. lemniscatus* in the West Beach area on the leeward side of the southern part of CCP was first confirmed by observation of two lizards in 2005 and one adult male in 2006, and one female photographed in 2006 (Figs. 1, 2B; Table 1). Here, habitat for *C. lemniscatus* begins about a meter from the high tide line and extends across a sliver of flotsam covered beach of 3–10 m in width, and culminates at a line of trees and shrubs and/or exposed rocks and soil of an eroded natural earthen wall criss-crossed by tree roots. Beyond the wall, the forest canopy presents shaded and ground littered habitat unsuitable for use by *C. lemniscatus*. We infer that no more than a few dozen lizards could be present at West Beach, a small patch of habitat that is vulnerable to storm surge inundation (Fig. 2B).

The presence of a colony of *C. lemniscatus* on CCP was first vouchered by KU 220101 obtained in 1988 from Playa 2 on the northern isthmus (Fig. 1) that connects the main part of the island to Bonkes Nose Point (Wilson and Cruz-Diaz 1993). The narrowest part of the isthmus is < 30 m across. Montgomery et al. (2007) reported that no whiptail lizards were seen along observational transects toward the middle of the isthmus in 2004 and concluded that thick canopy cover and lack of exposed substrate accounted for the absence of the species in this area. However, we observed two individuals of *C. lemniscatus* in 2005 and four juveniles in 2006 at Playa 2 along the inwardly curved leeward beach of the isthmus (Fig. 2C; Table 1), and seaward from the aforementioned transects. Here, lizards were active from the open beach into the edge of a palm grove (Fig. 2D). The distance from the high tide line to the edge of the open beach utilized by foraging lizards was about 2 m; with the edge of the palm forest starting about 8 m from tide line. The substrate at Playa 2 consists of sand, coral fragments, and fine flotsam in contrast to the rocky and debris-littered windward coast line east of the observational transects. Available habitat for *C. lemniscatus* at Playa 2 was limited southward at the termination of sandy beach owing to the encroachment of steeply sloped hill forest virtually to the high tide line (Fig. 2D). *Cnemidophorus lemniscatus* at Playa 2 appears to be separated by unsuitable habitat from those at West Beach, the HCRF compound, and East Beach on the southern part of CCP. Thus, migration by *C. lemniscatus* between Playa 2 and any

other currently occupied location would require movement through suboptimal habitat. The coast line of the eastern side of the isthmus is unsuitable for permanent colonization by *C. lemniscatus* owing to the rockiness of the exposed substrate, but conceivably could serve as a route of migration and dispersal from the south (Fig. 2E).

Two sites on CCP with relatively flat beach consisting of sand and coral fragments that appeared conducive to presence of *C. lemniscatus* were also repeatedly searched during the study. However, we did not observe *C. lemniscatus* at either Playa Uva or Playa 1 on the leeward side of the island (Fig. 1), most likely owing to inadequate numbers of lizards dispersing to these sites. Playa 1 beach is separated from both Playa Uva and Playa 2 beaches by encroachment of hill forest to near the tide line.

From 2004–2007, > 90% of all *C. lemniscatus* that we observed on CCP were in the East Beach windward zone of about 60 × 400 m located just east of the HCRF field station (Fig. 1, 2F; Table 1). By 2006, the beach to sea-wind scrub to coconut palm transition zone at East Beach had suffered a substantial loss of habitat due to an increase in the size of a helicopter landing pad. The area used by *C. lemniscatus* at East Beach presents a combination of open non-vegetated beach with scattered driftwood (Fig. 2F), inland to scattered clumps of (Sea Grape (*Coccoloba uvifera*) and other shrubby plants and thick low-lying Beach Morning Glory (*Ipomoea pes-caprae*), and into coconut palm grove. The palm zone ended at hill forest consisting mainly of Evergreen Oak rees (*Quercus oleoides*). Although we observed *C. lemniscatus* in the palm zone area up to ~60 m from the ocean, most lizards were within 10 m of the water's edge.

That *C. lemniscatus* occasionally penetrates upland forest with ground litter covering the soil by using man-made hiking trails and small clearings was indicated by a lizard observed there in 2005 (Table 1). It was sighted near the hiking trail extending northward from the HCRF compound, about 250 m from East Beach (Fig. 1). Apparent limiting factors to more than a token presence by *C. lemniscatus* in this forest setting on CCP are threefold: presence of large numbers of *Ctenosaura melanosterna*, minimal sunny breaks in shade from the mainly evergreen oak canopy, and compacted substrate.

Behavioral responses.—Individuals of *C. lemniscatus* were most consistently observable as they emerged from fringing vegetation along East Beach for forays to the open beach in and around driftwood/flotsam (Fig. 2F). That this behavior, shown by both sexes and all age classes of lizards, included foraging strategies for unusual food items was indicated by the presence of beach-dwelling amphipods in the diet. However,

behaviors associated with reproduction cannot be ruled out since these activities are not mutually exclusive with foraging, both of which can also expose lizards to threats from predators.

During periods of peak activity observed for *C. lemniscatus,* between 0900 and 1100 hours, we encountered individuals at ca. 5 m intervals along East Beach. Noticeably lacking from these sightings were more than occasional adult males, which could be easily identified by their spotted sides and blue-green faces. On the open beach, lizards employed one of two escape/retreat behaviors after detecting the approach of a human. Approximately 20% of the lizards retreated to the nearest available cover along the fringe vegetation where most of them were initially observed. That refuge was usually under stands or individual bushes of *C. uvifera* or other similarly structured vegetation. If the observer did not continue to approach, the lizard would often turn back and look toward the impending "predator" instead of retreating further out of view. At this point they would perform their characteristic hand-wave behavior, often done with alternating forelimbs. If the observer continued to approach, lizards would sometimes remain motionless or only move slightly, yet still remaining clearly in view. These observations indicate such lizards were exhibiting an apparent avian predator avoidance behavior. Lizards retreating to vegetation would be protected from aerial attack due to concealment under the bush canopy. About 80% of Rainbow Whiptail would either rapidly flee out of sight to deep stands of *C. uvifera* or would continue fleeing away from the beach (running through these bushy areas and into the thick *Ipomoea* or grass stands), which seemed to be a strategy for escaping active terrestrial predators, such as Brown Racer (*Dryadophis melanolomus*).

Diet.—We examined stomach contents to assess the extent of herbivory and habitat-specific food items in the diet of *C. lemniscatus* from CCP. Of the 25 lizards that we preserved, 19 of 21 used in the analysis had food in their stomachs. We identified 96% of the food items as arthropods and 4% as plant material. By volume, 77% of gut contents was arthropods, with 23% of the total volume consisting of plant material. Nineteen of 21 (90%) lizards we examined contained arthropods, while five of 21 (24%) contained plant material. The most abundant food items were termites (Isoptera), beach fleas (Amphipoda), adult beetles (several families of Coleoptera), various forms of Hymenoptera, and spiders (Araneae; Table 2). About half (55.9%) of all food items consumed were termites, although the value is inflated due to one lizard consuming 179 termites. By volume, the most abundant food items were beetle grubs (Coleoptera larvae; 21.5%), flowers (19.2%), adult

TABLE 2. Total number, total volume (mm³), and percentage frequency (percentage of lizard stomachs containing food category) of prey categories in the stomachs of *Cnemidophorus lemniscatus* collected from Cayo Cochino Pequeño, Cayos Cochinos Archipelago, Department of Islas de la Bahía, Honduras, in 2005 and 2006. Sample size was 21 lizard stomachs (of which two had nothing).

Food Item	Total Number	Total Volume	Percentage Frequency
AMPHIPODA	45	268.8	48
ISOPODA	3	45	14
ARANEAE			
Lycosidae	16	492.9	29
Salticidae	3	14.8	10
PSEUDOSCORPIONIDA	1	2	5
ORTHOPTERA			
Acrididae	2	15.7	10
ISOPTERA	189	223	19
HOMOPTERA			
Cicadellidae	13	72.1	10
Fulgoroidea	1	23.5	5
COLEOPTERA-ADULTS			
Scaphidinidae	17	8.5	10
Chrysomelidae	2	86	10
Carabidae	1	0.7	5
Elateridae	3	5.2	5
Unknown	10	468.6	33
COLEOPTERA-LARVAE	6	971.6	10
NEUROPTERA			
Myrmeleonidae-larvae	1	15.7	5
DIPTERA			
Phoridae	1	0.9	5
Muscidae	2	25.5	10
Tabanidae	1	28.4	5
LEPIDOPTERA-ADULTS	1	22.3	5
LEPIDOPTERA-LARVAE	2	544.8	10
HYMENOPTERA			
Sphecidae	11	88.8	33
Halictidae	2	12.3	10
Formicidae	18	59.3	24
UNIDENTIFIABLE INSECT	5	2.1	24
PLANT MATERIAL			
Leaves	1	28.7	5
Flowers	2	869.5	10
Stems	3	47.6	10
Seeds	8	80.1	5
TOTAL	370	4524.4	

beetles (12.6%), caterpillars (Lepidoptera larvae; 12.0%), and spiders (11.2%; Table 2). Again, results are biased by the stomach contents of individual lizards including one lizard that consumed three large beetle grubs, another that consumed a single large flower, and a third that consumed a large caterpillar. Numeric Diet Niche breadth was low for *C. lemniscatus* on CCP at 3.49 due to the large number of termites consumed. Volumetric Niche Breadth was slightly higher at 7.81. There was no significant correlation between lizard SVL and the total volume of food consumed (r = 0.312; P = 0.193).

Sex ratio, sexual dimorphism, and size.—Based on preliminary observations of differences in attributes of body size and sex ratio among Central American populations of *C. lemniscatus*, we compared CCP specimens with samples from Honduras and Panama. We captured 39 *C. lemniscatus* (15♂:24♀) from CCP throughout the study. The number of captures varied by year, with seven in 2004 (3♂:4♀; weighed, measured, and released), 20 in 2005 (5♂:15♀; vouchers), five in 2006 (3♂:2♀; vouchers), and seven in 2007 (4♂:3♀; released). Among years, only the sex ratio in the 2005 sample was significantly different from 1:1 (X^2 = 5.0, df = 1, $P > 0.05$). The lack of males of all sizes in the 2005 sample of *C. lemniscatus* is consistent with the previously noted observation that fewer males were observed, as well as collected, on East Beach during acquisition of voucher specimens.

TABLE 3. Comparisons of snout vent length (SVL) of adult female and male *Cnemidophorus lemniscatus* in four samples from Honduras (Cayo Cochino Pequeño [CCP], Isla de Utila, Isla de Roatán, and mainland [ML]), one sample from Panama, and one sample from Florida (introduced). For each sample by sex, data are presented as mean ± one SE, then range of variation, then sample size (N). All different superscript letters indicate significantly different means ($P = 0.05$) based on Tukey-Kramer HSD.

Sex	CCP	Utila	Roatán	Honduras-ML	Panama	Florida
Females	61.2 ± 1.34^{bc}	57.6 ± 1.14^{c}	61.0 ± 3.42^{bc}	68.3 ± 2.42^{ab}	73.6 ± 1.46^{a}	61.2 ± 1.98^{bc}
	51–67	50–67	54–68	66–70	71–78	54–64
	N = 13	N = 18	N = 2	N = 4	N = 11	N = 6
Males	65.7 ± 2.59^{b}	67.9 ± 1.99^{b}	75.0 ± 2.73^{ab}	76.6 ± 2.12^{a}	79.7 ± 2.37^{a}	71.0 ± 3.10^{ab}
	61–75	61–74	64–86	61–92	55–93	61–88
	N = 10	N = 17	N = 9	N = 15	N = 12	N = 7

Of the 39 captured lizards, 20 were juveniles (6♂:14♀) and 19 (9♂:10♀) were adults (Fig. 3). Juvenile and young adult males were difficult to distinguish from females of *C. lemniscatus* in the field prior to capture. Based on the color pattern of *C. lemniscatus* on Isla de Utila (Gutsche 2005; Montgomery pers. obser./photographs), males with essentially complete ontogenetic development of the dorsal striping pattern were expected to also consistently possess bluish lateral cephalic coloration, although this was not the case in some of the largest adult males observed on CCP (Fig. 3).

In CCP *C. lemniscatus*, maturity based on 57 mm SVL (size of the smallest gravid female), SVL means of adult males (67.7 ± 1.69 mm; N = 9) and females (63.6 ± 1.60 mm; N = 10) were not significantly different (t = 3.05, $P = 0.099$). In addition, there was no significant difference in the relationship of LogBM to LogSVL between adult male and adult female *C. lemniscatus* from CCP ($F_{1,17} = -1.74$, $P = 0.10$), with the assumption of homogeneous slopes met ($F_{1,17} = -0.05$, $P = 0.96$). Body mass of adult males (7.6 ± 0.50 g) from CCP was significantly greater than in adult females (6.0 ± 0.50 g; t = 2.34, $P = 0.017$).

When comparing body size across all populations of *C. lemniscatus* (CCP, Roatán, Utila, mainland Honduras, Panama, and Florida), we designated 50 mm SVL as the minimum adult size and analyzed males and females separately to account for possible variation among populations (Mesquita and Colli 2003; Mojica et al. 2003). Adult male SVL varied significantly across all populations ($F_{5,48} = 5.26$, $P < 0.001$). Adult males from Panama (79.7 ± 2.37 mm; N = 12), mainland Honduras (76.6 ± 2.12 mm; N = 15), Roatán (75.0 ± 2.73 mm; N = 9), and Florida (71.0 ± 3.10 mm; N = 7) were not significantly different from each other and adult males from Roatán, Florida, Utila (67.9 ± 1.99 mm; N = 17), and CCP (65.7 ± 2.60 mm; N = 10) were not significantly different from each other (Tukey HSD, q = 2.94; Table 3). However, adult males from Panama and Honduras were significantly larger than those from Utila and CCP (Tukey HSD, q = 2.94; Table 3). Adult female SVL also varied significantly among populations ($F_{5,64} =$

16.61, $P < 0.001$). Adult females from Panama (73.6 ± 1.46; N = 11) and mainland Honduras (68.3 ± 2.42 mm; N = 4) were not significantly different from each other (Tukey HSD, q = 2.97; Table 2). Adult females from Honduras, CCP (61.2 ± 1.34 mm; N = 13), Florida (61.2 ± 1.98 mm; N = 6), and Roatán (61.0 ± 3.42 mm; N = 2) were not significantly different from each other (Tukey HSD, q = 2.97; Table 3). Adult females from CCP, Florida, Roatán, and Utila (57.6 ± 1.14 mm; N = 18) were not significantly different from each other (Tukey HSD, q = 2.97; Table 3). However, adult females from Panama were significantly larger than those from CCP, Florida, Roatán, and Utila (Tukey HSD, q = 2.97; Table 3).

Reproductive characteristics.—We undertook analyses to determine clutch size and size at maturity in *C. lemniscatus* from CCP. Seven of 17 females we collected on 17 July (N = 3), 25 July (N = 3), and 3 August (N = 1) contained yolked ovarian follicles or oviductal eggs. The seven females had a mean SVL of 63.9 ± 1.39 (57–67) mm and mean potential clutch size of 1.7 ± 0.18 (1–2) eggs. The smallest reproductive female from CCP was 57 mm SVL, indicating the approximate minimum size of maturity. Yolked ovarian follicles found in four females averaged 5.5 ± 1.09 mm; range 3.0–9.0 mm) in length and varied as much as 1.5 mm within an individual female. There was no significant difference in ovarian follicle size among CCP, Panama (8.0 ± 1.09 mm, N = 4), Florida (5.3 ± 1.06 mm, N = 4), and mainland Honduras (4.5 ± 1.54 mm, N = 2; $F_{3,10} = 1.73$, $P = 0.223$). The mean size for oviductal eggs in three clutches from CCP was 8.3 ± 0.48 mm in width and 15.3 ± 0.53 mm in length. There was significant variation in oviductal egg length among populations ($F_{3,9} = 6.31$, $P = 0.0014$). There was difference in oviductal egg length among populations from Panama (18.3 ± 0.37 mm, N = 6), Florida (17.2 ± 0.70 mm, N = 2), or mainland Honduras (16.8 ± 0.64 mm, N = 2; Tukey HSD, q = 3.12), and there was no significant difference in oviductal egg length among Florida, Honduras, and CCP populations (Tukey HSD, q = 3.12). However, oviductal egg length in specimens

from Panama was significantly greater than those from CCP (Tukey HSD, q = 3.12). There was no significant difference in clutch size among CCP (1.7 ± 0.22, N = 7), mainland Honduras (2.3 ± 0.29, N = 4), Panama (2.4 ± 0.19, N = 10), and Florida (2.3 ± 0.24, N = 6; $F_{3,23}$ = 2.10, P = 0.13).

There was no significant relationship between clutch size and SVL when all populations were examined together ($F_{1,25}$ = 3.69, P = 0.067). When populations were examined individually there was a significant relationship between clutch size and SVL for the CCP population (r^2 = 0.817, $F_{1,5}$ = 22.32, P = 0.0052), but not for mainland Honduras ($F_{1,2}$ = 0.19, P = 0.707), Florida ($F_{1,4}$ = 0.71, P = 0.447), or Panama ($F_{1,8}$ = 0.012, P = 0.915). A significant relationship between clutch size and SVL in *C. lemniscatus* has been reported previously (Vitt et al. 1997).

DISCUSSION

Cayo Cochino Pequeño with an area of only 0.64 km^2, the second largest among the two islands and 13 cays in the Cayos Cochinos Archipelago, Honduras, is the only land mass of the group inhabited by *C. lemniscatus*. We cannot know with certainty whether its absence on Cayo Cochino Grande, the larger island in the archipelago with an area of 1.55 km^2 situated 1.6 km from CCP, is a consequence of island ecology (i.e., mainly hilly topography and only 3.3% flat land) rather than biogeography (dispersal failure). The dispersal capabilities and vagaries of the species are indicated by the presence of populations on the more distant Honduran bay islands from CCP, Utila and Roatán (McCranie et al. 2005), but apparent absence on Guanaja only 12 km from Roatán.

To our knowledge, CCP is the smallest island on which the natural history of *C. lemniscatus* has been studied. Over 95% of the lizards observed on CCP were in relatively natural windward habitat at East Beach and leeward West Beach, and Playa 2. Three lizards in the HCRF compound and one along the hill forest trail were the only examples observed in man-created habitats of the sort that are crucial to presence of the species in many parts of its range (Sexton et al. 1964; Serena 1984, 1985; Vitt et al. 1997; Mojica et al. 2003), and where introduced in Florida (Conant and Collins 1998; Meshaka et al. 2004; Butterfield et al. 2009). Indeed, the presence of this species at some sites (e.g., in Suriname and Brazil), has been directly attributed to the habitat-altering activities of humans (Serena 1984, 1985; Vitt et al. 1997).

There are marked ecological similarities between *C. lemniscatus* on CCP and other populations of the species, as well as to C. *nigricolor,* an insular derivative

of *C. lemniscatus* (Walker and Rhoads 2003) in Los Roques Archipelago, Venezuela (Paulissen and Walker 1994, Walker and Rhoads 2003). For example, *C. lemniscatus* on CCP exhibits the same distinctive waving of the forelimbs as noted by Serena (1984) for individuals of this species in Suriname. In fact, McCranie et al. (2005) noted that *C. lemniscatus* is known as "Wave Paw" by locals on CCP, as well as on Islas de Utila and Roatán (Wilson and Hahn 1973).

Based on body size, CCP individuals of *C. lemniscatus* are more similar to lizards from the nearby Bay Islands Roatán and Utila than to the possible mainland source populations in Honduras and Panama. *Cnemidophorus lemniscatus* body size similar to that seen on CCP has also been reported in Brazil (Vitt et al. 1997) and in Colombia (Mojica et al. 2003). The diet of *C. lemniscatus* on CCP is similar to previous reports of *C. lemniscatus* primarily consuming arthropods, such as beach fleas (Amphipoda) and various types of insects (including termites when they can be found), but also in consuming flowers, seeds, and other plant material (Mijares-Urrutia et al. 1997; Vitt et al. 1997; Mesquita and Colli 2003). The diet of *C. lemniscatus* on CCP is most similar to that of *C. nigricolor*, an insular species from Los Roques Archipelago (e.g., Grand Roque Island), Venezuela (Paulissen and Walker 1994).

Mojica et al. (2003) reported size at maturity for males and females of *C. lemniscatus* from Colombia to be 48 and 51 mm, respectively, and a clutch mean and range of 2.17 ± 0.48 (1–3) eggs. Mesquita and Colli (2003) reported size at maturity for males and females from Brazil to be 51 and 49 mm, respectively, and a clutch mean and range of 1.50 ± 0.52 (1–2) eggs. Gutsch (2005) discovered separate groups of four and five *C. lemniscatus* eggs on a beach on Isla de Utila, with an average size of 9.8 mm in width and 16.4 mm in length, which is similar to the size reported here for CCP. The large clutch sizes discovered on Isla de Utila are interesting relative to the smaller clutches from females from Panama, Columbia, and CCP, which we consider to be representative of their respective populations. However, there is no evidence to confirm that each group of eggs found on Utila was from a single female. The sample of gravid females from CCP is small; however, sacrifice of a larger number of adult females from this small island would not be prudent in terms of conservation and would unlikely significantly affect the SVL and clutch means reported.

Within Honduras, *C. lemniscatus* is not considered highly vulnerable due to its widespread distribution within and outside of the country and the fact that it is generally ignored by humans (Wilson and McCranie 2004). However, *C. lemniscatus* occupies only one Holdridge forest formation (Holdridge 1967), which

increases the environmental vulnerability of the species (Wilson and McCranie 2004). Cayo Cochino Pequeño is one of the smallest insular land masses occupied by *C. lemniscatus*. Established groups of *C. lemniscatus* are limited to the East Beach-HCRF-West Beach continuum and the sliver of beach and coconut grove at Playa 2 on the west side of the narrow northern isthmus, sites from which the species could conceivably be extirpated by any single human or natural perturbation, such as habitat modification, over collection, or severe storm surge event. Should the island become more developed, which is open to conjecture, such development would almost surely involve the East Beach coastal zone and present a serious threat to the continued presence of *C. lemniscatus* in that area. However, if the island remains more or less as it is today, *C. lemniscatus* is likely to persist indefinitely, but without a substantial increase in its distribution on CCP due to habitat limitations.

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APPENDIX 1. Mass in g and measurements in mm and for individuals of *Cnemidophorus lemniscatus* collected in 2004–2006 from Cayo Cochino Pequeño, Cayos Cochinos Archipelago, Department of Islas de la Bahía, Honduras. Abbrievations: F, female; M, male; UADZ number (Robert N. Reed field number) for preserved specimens, R (with number), released lizards; BM, body mass; LSVL, live snout vent length; LTL, live tail length (* tail regenerated); and PSVL, preserved snout-vent length.

SEX UADZ.	DATE	BM	LSVL	LTL	PSVL
M 8821 (197)	17/7/2005	6.0	64	161	61
M 8822 (193)	17/7/2005	10.0	78	121*	75
F 8223 (194)	17/7/2005	7.0	68	75*	67
F 8224 (195)	17/7/2005	4.0	61	149	57
F 8225 (198)	17/7/2005	0.9	30	67	30
F 8226 (199)	17/7/2005	8.0	66	153	66
M 8227 (200)	17/7/2005	7.0	65	147	65
F 8228 (196)	17/7/2005	5.0	61	142	61
F 8229 (192)	17/7/2005	3.0	51	126	49
F 8230 (191)	25/7/2005	6.0	66	156	64
F 8231 (188)	25/7/2005	6.0	66	51*	64
F 8232 (187)	25/7/2005	3.0	52	139	52
F 8233 (189)	25/7/2005	2.0	43	104	42
M 8234 (190)	25/7/2005	2.0	44	106	44
F 8235 (186)	25/7/2005	–	–	–	67
M 8236 (183)	25/7/2005	0.9	33	76	32
F 8237 (184)	25/7/2005	2.0	45	113	46
F 8238 (185)	25/7/2005	7.0	66	152	65
F 8239 (182)	26/7/2005	3.0	51	63*	51
F 8240 (181)	26/7/2005	2.0	44	112	46
M 8241 (140)	03/8/2006	5.0	60	129*	62
M 8242 (141)	03/8/2006	8.0	69	132*	69
F 8243 (142)	03/8/2006	2.2	43	106	42
M 8244 (143)	03/8/2006	2.4	46	113	45
F 8245 (144)	03/8/2006	5.2	57	81*	57
F 01 (R)	07/7/2004	0.8	35	79	–
M 02 (R)	12/7/2004	8.3	72	166	–
F 03 (R)	12/7/2004	5.5	67	153	–
F 04 (R)	18/7/2004	0.9	26	58	–
M 05 (R)	15/6/2004	7.0	66	160	–
M 06 (R)	18/8/2004	10.3	74	175	–
F 07 (R)	22/8/2004	3.3	45	113	–

APPENDIX 2. Numbers (N) of museum specimens used for SVL comparisons within and among regional populations of *Cnemidophorus Lemniscatus* (museum abbreviations given in text).

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Cayo Cochino Pequeño, Honduras (N = 25): UADZ 8221–8245.
Isla de Utila, Honduras (N = 30): FLMNH 28366–28383, 28385–28388, 28430–28436, 28444.
Isla de Roatán, Honduras (N = 11): FLMNH 28509–28513, 28534, 28554–28556; KU 192621, 192622.
Honduras (mainland) (N = 28): KU 101328–101351, 203160–203161, 200562, 208859.
Panama (N = 24): KU 80562–80574, 80576–80577, 107577–107578, 107590–107591, 107599, 107605, 107608, 107616, 107619.
Florida Introduced (N = 15): BPB 1960-1968, AUM 34112, 34113, FLMNH 131480–131482, 131539.

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APPENDIX 3. Numbers (N) of museum specimens and clutch size (in paren) for each one used for analyses of reproductive characteristics among regional populations of *Cnemidophorus lemniscatus* (museum abbreviations given in text).

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Cayo Cochino Pequeño, Honduras (N = 7): UADZ 8223 (2), 8226 (2), 8228 (1), 8230 (2), 8235 (2), 8238 (2), 8245 (1).
Honduras (Honduras) (N = 4): KU 101332 (2), 101333 (2), 101334 (3), 101340 (2).
Panama (N = 10): KU 80572 (1), 80573 (2), 80574 (2), 80576 (3), 80577 (2), 107591 (2), 107599 (3), 107605 (3), 107608 (3), 107616 (3).
Florida (N = 6): BPB 1960 (3), 1961 (2), 1962 (2), 1964 (3), AUM 34112 (2), 34113 (2).

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