
GROWTH, REPRODUCTION, AND DIET OF ROATAN SPINY-TAILED IGUANAS, *CTENOSAURA OEDIRHINA*, WITH NOTES ON THE STATUS OF THE SPECIES

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Abstract.—Roatan Spiny-tailed Iguanas, *Ctenosaura oedirhina*, are listed as Endangered by the IUCN Redlist Assessment and under Appendix II of Convention on International Trade of Endangered Species of Wild Fauna and Flora (CITES). These iguanas occur primarily on Roatan and Barbaretta, off the Caribbean coast of Honduras. Habitat destruction associated with development, small-scale agriculture, and exploitation for food and the pet trade are contributing to the decline of these iguanas. This species was described in 1987 (de Queiroz) when it was split from the sister taxon *C. bakeri*, found on the island of Utila, Honduras. Since its description little has been done to understand its biology or protect this narrow-range endemic. Herein, I examined the morphology and body condition of this species across its range and report on its reproductive biology and diet. Similar to many members of the Iguaninae, males are larger on average and have relatively longer tails than females. Likewise, reproductive and dietary data are consistent with those for closely related species. The body condition of both males and females was lower in more pristine study sites, indicating that supplemental feeding in developed areas may be having an effect. A female-biased sex ratio was found in sites protected by grassroots efforts, where the populations were large enough to be studied. Conservation measures should focus on alleviating the threats of harvesting and habitat destruction through increased law enforcement, outreach, and education.

Key Words.—Bay Islands; endangered; Honduras; iguana; *palearis*; size

INTRODUCTION

Roatan Spiny-Tailed Iguanas, *Ctenosaura oedirhina* de Queiroz 1987, are endemic to Roatan, Barbaretta, and some small surrounding cays, located within the Bay Islands, Honduras (Pasachnik et al. 2010a; McCranie et al. 2005). This species belongs to the *C. palearis* clade (along with *C. palearis*, *C. bakeri*, and *C. melanosterna*; Pasachnik et al. 2010b), a recent radiation of narrow-range endemics found in Honduras and Guatemala. *Ctenosaura oedirhina* is distinguished from similar species based on morphology (de Queiroz 1987, 1990), and confirmed with more recent molecular analyses (Pasachnik et al. 2010b).

A decade ago *C. oedirhina* was recognized as the second most vulnerable species in Honduras, due to its small geographic range and harvesting of meat and eggs, though the population was thought to be stable (Wilson and McCranie 2003b). This species was also listed as an indicator species for Honduras, demonstrating that a sustainable human society was needed in order for species such as *C. oedirhina* to persist (Wilson and McCranie 2003a). In 2010, The World Conservation Union (IUCN) evaluated the status of *C. oedirhina*, resulting in an Endangered listing (Pasachnik et al. 2010a), because of the aforementioned reasons as well as

increased habitat modification for development. Also, in 2010 the Convention on International Trade in Endangered Species (CITES) listed *C. oedirhina* under Appendix II (species in which trade must be controlled to avoid utilization incompatible with their survival) (Pasachnik and Ariano 2010). Although the Honduran government designated *C. oedirhina* as in need of protection in 1994 (Pasachnik et al. 2010a), virtually no protection is actually afforded to this species from the federal or local government authorities. Thus, the protection that is given comes from grassroots efforts within the local community, prohibiting habitat destruction and harvesting on private property.

The Bay Islands, and Roatan in particular, are becoming an increasingly popular tourist destination, causing extensive commercial and residential development. This situation threatens native species through habitat destruction, the introduction of invasive species, and pollution. From 1985 to 2001, the urban areas increased from 1.18 km² to 17.1 km², and the sandy beach areas decreased from 4.06 km² to 0.81 km² (Aiello 2007). Further, over the duration of this study new developments were constantly taking place. In turn, this development creates job opportunities, causing an influx of potential employees from the mainland, not all of whom can find work. Iguana meat is a more common

component of the diet on the mainland (unpubl. data). As poverty increases on Roatan, the use of wild protein sources, such as *C. oedirhina*, is increasing. The lack of active protection through enforcement exacerbates this situation.

In addition the recent human introduction (for unknown reasons) of a wide-ranging congener, *C. similis*, to a nearby cay (ca. 100 m) and in July 2012 to Roatan, has the potential to threaten the native *C. oedirhina*. Invasive *C. similis* have the potential to threaten native biodiversity and become dominant within the invaded community (e.g., Lopez-Torres 2012). In addition, hybridization between members of the *C. palearis* clade and *C. similis* is possible, as has been shown on Utila with *C. bakeri* (Pasachnik et al. 2009). Thus, this is a problematic situation that should be investigated further and mitigated.

Ctenosaura oedirhina is a unique and threatened species that has been largely overlooked in organized conservation efforts in the Bay Islands and by biologists in general, with the exception of a brief morphological evaluation of the species in 1994 (Köhler 1995) and captive information (Rittmann 2007). Early in the course of the present study, it was clear that members of the local community knew very little about this species and its ecological role, but that they must play a critical role if protection of this species is to be achieved. In this study, I examined iguanas from throughout the range, while documenting and evaluating grassroots protection efforts. Specifically, my objectives were to: (1) document basic biometrics for the species; (2) examine differences in body condition index across sites and sexes; and (3) describe the reproductive biology and diet. This basic information is vital to understanding the status of the species and in the development of a comprehensive conservation and management plan.

MATERIALS AND METHODS

Study site.—Roatan is the largest of the Bay Islands, located approximately 48 km N of mainland Honduras (McCranie et al. 2005), and is an oceanic island. Although Roatan encompasses approximately 160 km², the area occupied by *C. oedirhina* is likely much smaller. Preliminary data suggests that there are areas where this species is not found and more rigorous studies are currently underway to better understand its distribution and use of various habitat types across the island. Though Köhler (1995) described this species as being found in the dry forest habitat, the historic range of this species most likely included much of the island, as I observed iguanas in a variety of habitats, including mangrove, beach, karst limestone, and scrub forest. The climate of Roatan is tropical, with two distinct rainy seasons, occurring roughly in November and February. Annual rainfall is 2.33 m and temperatures range from

19° C to 33° C (climatic data from two weather stations logging to www.weatherunderground.com). Roatan consists of a range of hills running throughout the spine of the island, such that the elevation in most areas is greater than 20 m, with the highest point on the island being 235 m (McCranie et al. 2005). I examined sites across the island, including all major habitat types. Because this is an endangered species, references to specific localities are not included here; however, localities may be available (to legitimate researchers) upon request to the author.

Data collection.—I opportunistically captured 535 *Ctenosaura oedirhina* from August 2010 through November 2011, using noosing poles, nets, and by hand. These individuals came mainly from six locations across the island that have differing levels of human impact but all are protected to some degree. This protection is afforded only because the private owners keep hunters off of their property, and moderate development. I did not use completely pristine areas for these analyses because very few to no iguanas could be found in such areas on the island. Most sites have a variety of habitat types, including mangrove forests (all but site two), sandy beachfront shoreline (all sites), tropical wet forests (all sites), and human impacted areas (all sites). Human impacted areas commonly contained introduced flora, cleared areas with no forest, high densities of tourists, and feral mammals. In addition, site five has a section of rocky shore, site six is a small and separate island, and only site three includes tropical dry forest. Sites one, two, and four have the greatest anthropogenic effects, as they are eco-reserve tourist attractions. Sites five and six have the lowest levels of human influence. Sites three and five are under ownership of private resorts. Samples sizes within these main areas ranged from 12 (site one) to 142 (site two) with the two most disturbed areas being at these two extremes.

After processing, I took a digital photograph of the left side of each individual. I recorded snout-vent length (SVL), tail length (TL) and total body mass (BM). I measured SVL and TL to the nearest mm using a tape measure and BM to the nearest 0.5 g using Pesola spring scales. I determined sex on the basis of external morphology (e.g., femoral pores, head width) and cloacal probing (Dellinger and von Hegel 1990). To permanently identify adults, I placed bead tags on the nape (Rodda et al. 1998) and passive integrated transponders (PIT tags) subcutaneously. I used non-toxic paint marks to temporarily identify individuals. Processing lasted no more than 15 min and I released all individuals at the site of capture. I gathered reproductive data by excavating nests, radio telemetry (of adult males and females), and direct observation of courting and mating behaviors. To the posterior dorsal lateral surface

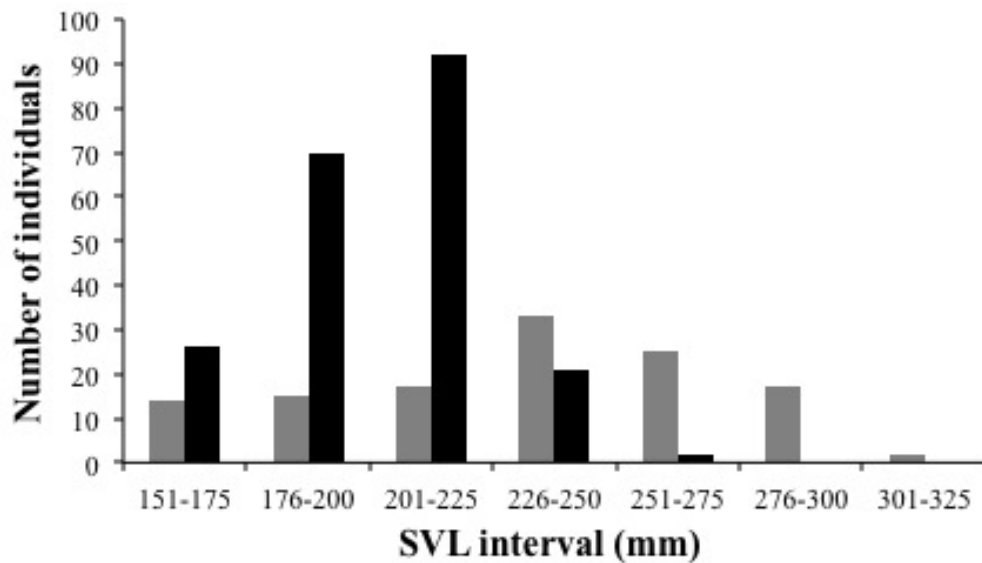


FIGURE 1. Frequency distribution of snout-vent lengths of adult male (black) and female (grey) *Ctenosaura oedirhina*

of the abdomen, I glued radio transmitters (RI-2C, Holohil Systems Ltd., Carp, Ontario, Canada) using 3M 5200 marine adhesive.

I gathered dietary data using direct observation of feeding and scat evaluation and I opportunistically collected fecal samples throughout Roatan, primarily from three long-term study sites. I also collected comparative plant materials concurrently in the field to use for identification of diet components. All fecal samples had been recently deposited, but I examined them after drying in a desiccation chamber. I separated and compared the various components, and I recorded the total number and type of item as well as the diameter of the scat sample at the greatest width, which I used to estimate iguana size.

Statistical analyses.—For all analyses, I considered individuals ≥ 150 mm SVL to be adults for both sexes based on Gutsche and Streich (2009) for *C. bakeri*. *Ctenosaura bakeri* is the closest relative of *C. oedirhina* and reaches a similar adult size. It should be noted, however, that this cutoff could create a bias in the data if individuals of the smaller sex are excluded or juveniles of the larger sex are included. I tested for sexual size dimorphism (SSD) in adult *C. oedirhina* by comparing SVL and mass separately between the sexes using t-tests. I examined SSD in the relationship between TL and SVL (using only individuals with complete tails) and in the relationship between mass and SVL using ANCOVA. Mass, TL, and SVL were log transformed to linearize the relationships. I plotted SVL of juveniles by day of year to summarize hatchling growth patterns.

I calculated a Body Condition Index as the residual of the relationship between log Mass and log SVL for each sex separately. To test for differences in BCI across SVL, I used least squares regressions by sex. To test for study site effects on body condition, I compared BCI using ANOVA for each sex separately with post hoc Tukey-Kramer analyses. I plotted BCI by sex over time to check for differences during the hypothetical reproductive period. I compared tail break frequencies between sexes using a Chi-square with Yates correction.

I addressed the relationship between body size and the number of items present within the fecal sample using least squares regression. I compared body size and location to the presence of non-vegetation items and inedible items using Chi-square tests. I used JMP 9.0.3 (SAS Institute, Durham, North Carolina, USA) for all statistical analysis, and $\alpha = 0.05$. All averages are reported $\pm$ one standard error.

RESULTS

Of the 535 individuals I captured, 128 were adult males, 210 adult females, 180 juveniles, and 17 were adults for whom sex could not be determined. Adult males were significantly longer (mean male SVL = 232.2 mm, ± 3.50 ; mean female SVL = 201.8 mm; ± 1.50 ; $t = 82.29$, $P < 0.001$) and heavier (mean male mass = 562.2 g; ± 25.24 ; mean female mass = 345.3 g; ± 8.67 ; $t = 92.83$, $P < 0.001$) than adult females (Fig. 1). The relationship between mass and SVL of adult males and females was not significantly different ($F_{1,1} = 0.75$, $P = 0.386$, Fig. 2), with the assumption of homogenous slopes met ($F_{1,1} = 0.64$, $P = 0.426$). However, adult

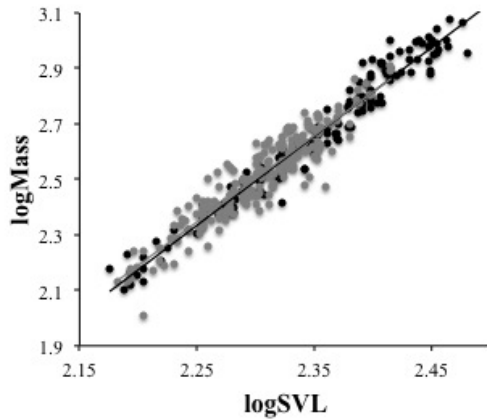


FIGURE 2. Relationship between Log Mass and Log SVL for adult male (black) and female (grey) *Ctenosaura oedirhina*.

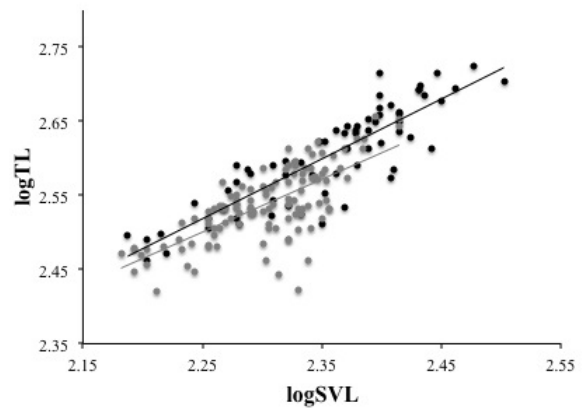


FIGURE 3. Relationship between Log Tail Length (TL) and Log Snout Vent Length (SVL) for adult male (black) and female (grey) *Ctenosaura oedirhina*.

males have significantly longer tails for a given SVL than females ($F_{1,1} = 17.66$, $P < 0.001$; Fig. 3), with the assumption of homogenous slopes being met ($F_{1,1} = 1.79$; $P = 0.182$). The tail break frequency (TBF) did not vary significantly between adult males (46%) and females (42%; $\chi^2 = 0.381$, $P < 0.537$). The adult sex ratio was 1:1.64, with significantly more females found ($\chi^2 = 19.89$, $P < 0.001$). There was no significant relationship between BCI and SVL for adult males ($F_{1,124} = 0.001$, $P = 0.998$) or adult females ($F_{1,208} = 0.001$, $P = 0.973$). However, there was a significant effect of location on BCI in both males ($F_{5,115} = 6.15$, $P < 0.001$) and females ($F_{5,193} = 3.94$, $P = 0.002$; Fig. 4).

From preliminary observations of courting and mating, aided by radio-telemetry nesting inferences, I estimated the approximate timing of reproductive behaviors. I observed courting from February through April, mating in March and April, nesting from March through June,

and hatching from May through September. From two nest excavations, I found that clutch size ranges from 4–7 eggs, and egg mass averaged 4.78 g (4.23–5.62 g). Mean egg dimensions were 27.26 x 18.69 mm. BCI was generally lower in males and females during the beginning of the presumed reproductive season (Fig. 5). The size distribution of juveniles by day of year (Fig. 6) suggests that hatchlings nearly double in SVL in their first year, and that 150 mm SVL (estimated maturity) is reached at approximately 2 y.

From observations and fecal analysis, I documented 29 different items in the diet of *C. oedirhina*. I recorded 17 different identifiable plant species (Table 1) and an additional seven non-vegetative items, including hatchling *Iguana iguana*, hatchling *Trachemys venusta* (Pasachnik and Chavarria 2011), birds, crabs, ants, flies, and their own shed skin. I also documented rocks, sand, iron (from rebar), plastic, and aluminum foil.

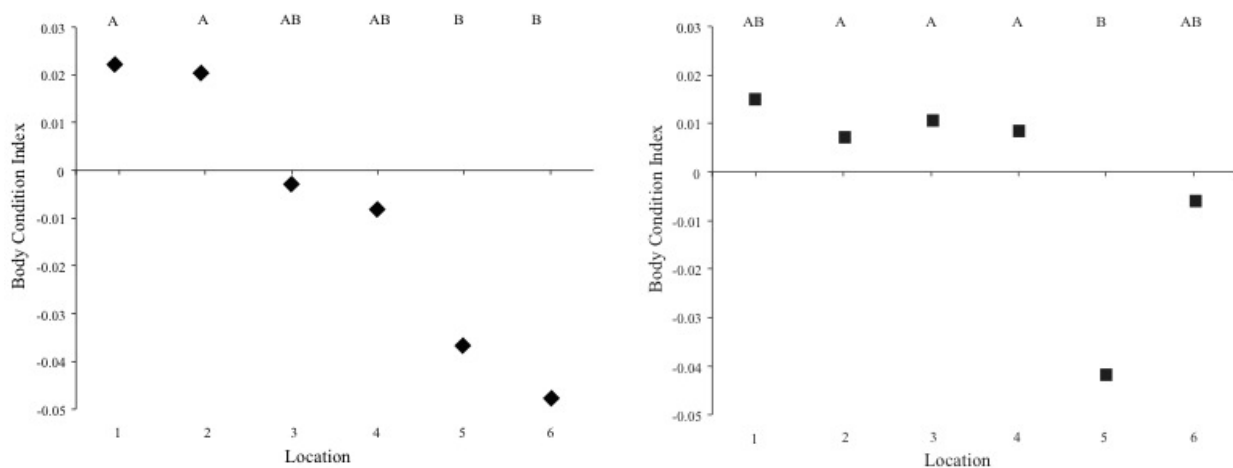


FIGURE 4. Body condition index for (a) male (diamonds) and (b) female (squares) *Ctenosaura oedirhina* across study sites. Numbers signify different study sites. Letters indicate significant differences for males ($q_s = 2.90$) and females ($q_s = 2.88$) separately as revealed by Tukey-Kramer post hoc tests.

TABLE 1. Plants included in the diet of *Ctenosaura oedirhina* based on an analysis of scat samples and through direct observations of feeding.

Scientific Name	Common Name
<i>Morinda citrifolia</i>	Noni
<i>Cordia sebestena</i>	Cocacola
<i>Coccoloba uvifera</i>	Sea grape
<i>Thrinax radiata</i>	Palm
<i>Calyptanthus hondurensis</i>	May Pole
<i>Spondias mombin</i>	Hog plum
<i>Couepia polyandra</i>	Monkey Cap
<i>Terminalia catappa</i>	Almond
<i>Anacardium occidentale</i>	Cashew
<i>Dactyloctenium aegyptium</i>	Grass
<i>Acrocomia aculeate</i>	Coyol
<i>Scaevola sericea</i>	Beach Naupaka
<i>Cissus microcarpa</i>	No common name
<i>Chamaesyce</i> sp.	No common name
<i>Acacia</i> sp.	No common name

Thirty-five percent of the fecal samples contained non-vegetative items and 12% contained the inedible items listed above. There was an average of 2.26 different items per sample. There was no observed relationship between body size and the number of items per sample ($F_{1,68} = 0.77$, $P = 0.383$), the presence of non-vegetative items ($\chi^2 = 1.10$, $P = 0.295$), or the presence of inedible items ($\chi^2 = 0.07$, $P = 0.796$). There was also no effect of location on the presence of non-vegetative items ($\chi^2 = 6.95$, $P = 0.139$) or inedible items ($\chi^2 = 5.85$, $P = 0.211$).

DISCUSSION

Ctenosaura oedirhina is a narrow-range endemic, threatened by harvesting for human consumption and direct habitat destruction (Wilson and McCranie 2003a, 2003b; Pasachnik et al. 2010a). Since the time of its description, little has been done to comprehensively describe the biology of this species and to aid in its protection. These data provide a baseline understanding that will be important for future monitoring and management making decisions.

As is the case with closely related species (Pasachnik et al. 2012a, 2012b) and within the Iguaninae in general (e.g., Wikelski and Trillmich 1997; Beovides-Cases and Mancina 2006) adult male *C. oedirhina* are larger than females. However, for a given SVL there is no difference in mass between the sexes. As is also common among lizards, adult males have longer tails than females for a given SVL, potentially due to the presence of hemipenes (King 1989; Barbadillo et al. 1995). There was no significant difference in tail break frequency (TBF) between sexes, although values were among the highest known for iguanas (Hayes et al. 2012). This could indicate high levels of attempted predation or poaching events, or it may be the result of intraspecific aggression (Knapp 2000; Hayes et al.

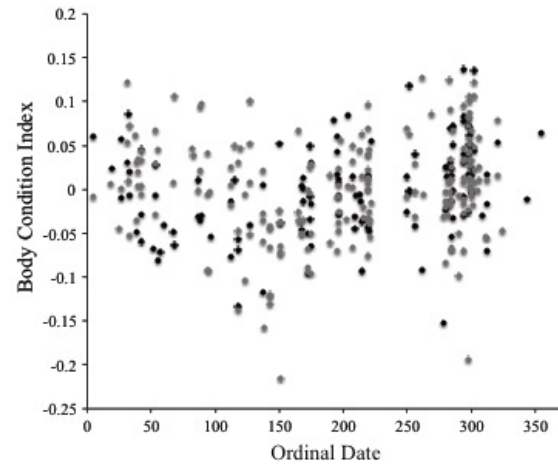


FIGURE 5. Body condition index for male (black) and female (grey) *Ctenosaura oedirhina* by ordinal date for years 2010 and 2011 combined.

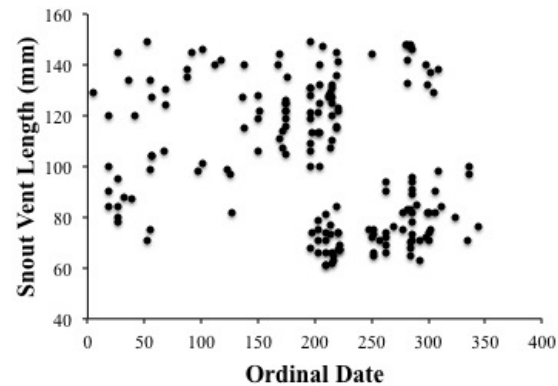


FIGURE 6. Juvenile snout vent length (SVL) of *Ctenosaura oedirhina* plotted by ordinal date for years 2010 and 2011 combined.

2012), which in turn could result from decreased habitat quality (Pasachnik et al. 2012a).

It is the case on Roatan, and more prominently on the adjacent mainland, that gravid females are preferred over other types of iguanas by people (Stesha Pasachnik et al., unpubl. data). This is said to be due to the increased amount of protein and medicinal benefits thought to come from the eggs (Stesha Pasachnik et al., unpubl. data). Though the sex ratio I observed is consistent with those found in stable iguanid populations (Fitch and Henderson 1977; Munoz et al. 2003) and not those that are under harvesting pressure (Pasachnik et al. 2012a, 2012b), the study areas herein are mostly protected by private landowners. Thus, these data cannot necessarily be seen as a demonstration of the overall stability of this species, as harvesting and large scale habitat destruction is more prevalent in the areas outside of my main focal sites. Analyses of the genetic structure of *C. oedirhina* across the island, which are now underway, demonstrate

isolation by distance and will soon shed additional light on the potential repercussions of harvesting (Stephen Hudman et al., unpubl. data).

Body condition index (BCI) varied significantly among sites with the less human impacted sites having a lower BCI. This is most likely the result of supplemental feeding that occurs within the semi-developed areas, and more diverse and potentially unnatural food sources. It is important to note that this increased BCI could be correlated with potentially negative effects on the overall health of individuals within those populations. Additional research should be conducted to better understand the health of these populations, as supplemental feeding can have negative effects on iguana populations (e.g., Hines 2011).

Herbivory is the most common dietary strategy within the iguanine group (Iverson 1982). *Ctenosaurs*, however, seem to stray from this strategy more than other Iguanine genera. The diet of *Ctenosaura oedirhina* documented herein is consistent with that of other ctenosaurs in that members of this species are primarily herbivorous but forage on a variety of other items (e.g., Campbell 1998; Durtsche 2000; Blázquez and Rodríguez-Estrella 2007; Torres-Carvajal 2007; Coti and Ariano 2008).

Our preliminary data concerning the timing of reproductive behaviors is largely consistent with that of the closely related *C. melanosterna* on Cayos Cochinos (Chad Montgomery et al., unpubl. data), and appears to be shifted slightly later in the year relative to *C. bakeri* (Gutsche 2006). The clutch size of *C. oedirhina* (4–7 eggs) seems to be slightly smaller than that of *C. melanosterna* on Cayos Cochinos (7–18 eggs per clutch; Chad Montgomery et al., unpubl. data), *C. bakeri* (average 9.8 eggs per clutch; Gutsche 2006) and *C. palearis* (6–12 eggs per clutch; Coti 2008). Likewise, the egg dimensions are slightly smaller than those of *C. bakeri* (mean egg mass 6.2 g, mean egg size 30.5 x 18.7 mm; Gutsche 2006). However, given the small sample size in this study, the fact that these data are slightly inconsistent with that from captive individuals (Rittmann 2007), and lack of information for other species, additional data are necessary to make robust comparisons within this clade.

The results presented herein provide vital baseline data for continued monitoring of *Ctenosaura oedirhina*. Through personal observations and interviews with the local community, I found that harvesting across the island can be intensive, resulting in an uneven and potentially disjunct iguana distribution across Roatan. In addition, development is rapidly destroying large plots of habitat that are used by this species, and an encroaching human population is increasing trash pollution and the presence of invasive species of predators, competitors, and potentially harmful food sources. Lastly the recent (July 2012) confirmation that

C. similis has colonized Roatan proper not only has the potential to increase competition for the native iguana but may also threaten this insular endemic through hybridization. In 2003, this species was noted as the second most vulnerable reptile in Honduras (Wilson and McCranie 2003b). A decade later, the threats are certainly not subsiding and are most likely expanding, demonstrating an increasingly more threatening situation for this species. Management and conservation initiatives, from the local community to the federal government, should focus on these imminent threats through education, species and habitat protection, and increased law enforcement.

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