MORPHOLOGICAL AND DEMOGRAPHIC ANALYSES OF THE BLACK-CHESTED SPINY-TAILED IGUANA, *CTENOSAURA MELANOSTERNA*, ACROSS THEIR RANGE: IMPLICATIONS FOR POPULATION LEVEL MANAGEMENT

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Abstract.—The Black-chested Spiny-tailed Iguana, *Ctenosaura melanosterna*, is listed as Endangered by the IUCN Redlist Assessment and under Appendix II of CITES. The species has two evolutionarily significant units (ESUs), found in the Valle de Aguán and the Cayos Cochinos Archipelago, Honduras. Each ESU has been shown to be genetically distinct and each is listed, for differing reasons, as Critically Endangered by the IUCN. Habitat destruction and overharvesting for consumption and the pet trade are among the top threats facing the mainland, Valle de Aguán, population. The Cayos Cochinos population faces similar threats to a lesser degree; however, its restricted range (2.2 km^2) heightens the potential severity of these threats, and makes this population highly susceptible to the impact of hurricanes. We examined body size, demography, and body condition in both populations. Our results show that the average adult size is smaller on the mainland, and there are more than expected small individuals in that population. Additionally the sex ratio is significantly male biased on the mainland relative to the islands. These results demonstrate evidence of a more severe poaching pressure on the mainland that is biased towards larger individuals and females. Body condition index did not differ between the more disturbed mainland area and the more pristine island area, suggesting that habitat alteration does not pose as serious a threat to the mainland population as poaching. Potential negative effects of a restricted range on the morphology and demography of the island ESU were observed. Conservation measures should acknowledge the differences between the ESUs when defining management initiatives for this species.

Key Words.—endangered; Cayos Cochinos; iguana; size; spiny-tailed; Valle de Aguán

INTRODUCTION

The Black-chested Spiny-tailed Iguana, *Ctenosaura melanosterna* (Buckley and Axtel 1997), is a medium-sized, spiny-tailed iguana, and a member of the *C. palearis* clade. The group consists of four narrow-range endemics (*C. palearis*, *C. oedirhina*, *C. bakeri*, and *C. melanosterna*; Pasachnik et al. 2010) occurring in Guatemala and Honduras. Two distinct evolutionarily significant units (ESUs) have been described for *C. melanosterna* (Pasachnik et al. 2011). One occurs within the arid tropical scrub forest of the Valle de Aguán, Honduras, and the other occurs primarily on two islands (Cayo Menor and Cayo Mayor) within the Cayos Cochinos Archipelago, Honduras. Overall the species is listed as Endangered by the IUCN Redlist Assessment, is listed on Appendix II of CITES, and has been recognized as one of the top four most vulnerable species in Honduras (Wilson and McCranie 2004). Each

ESU is listed as Critically Endangered based on differing causes. Factors associated with an extremely restricted range threaten the Cayos Cochinos ESU, whereas the mainland ESU is threatened primarily by habitat destruction and overharvesting (IUCN. 2011. IUCN Red List of Threatened Species, Version 2011.2. Available from www.iucnredlist.org [Accessed 01 September 2011).

Substantial variation exists between, and in some cases, within, the mainland and the island regions in terms of types and degrees of threats present and the level of protection afforded. The Cayos Cochinos ESU is within the Cayos Cochinos Archipelago Natural Marine Reserve (CCANMR) administered by the Honduran Coral Reef Foundation (HCRF). Thus, both Cayo Menor and Cayo Mayor are technically protected; however, Cayo Menor is more actively protected because of the presence of personnel associated with the HCRF research station. The iguana populations on both

Cayo Menor and Cayo Mayor are currently stable, but recent increases in the population density of Common Green Iguana (*Iguana iguana*) may result in competition for resources.

The human population on Cayo Menor consists of six permanent HCRF staff and periodically increases to approximately 100 people due to visiting citizen scientists, reality show filming, and researchers. The vast majority of the researchers and citizen scientists focus on marine research and do not venture far from the research station. The reality show activities take place primarily near the research station or on smaller cays. Cayo Mayor has a larger local population of approximately 100 permanent Garifuna residents located within the village of East End and approximately 25 tourists scattered across the island staying in vacation homes and a small hotel. The local Garifuna have hunted *C. melanosterna* on Cayo Mayor in the past, but indicate that they quit hunting them a few years ago.

Invasive mammals, including Domestic Dogs (*Canis familiaris*), Domestic Cats (*Felis catus*), Black Rats (*Rattus rattus*), House Mice (*Mus musculus*), Central American Agouti (*Dasyprocta punctata*), and Paca (*Cuniculus paca*) occur on Cayo Mayor. The number of invasive mammals on Cayo Mayor appears to be increasing, particularly with the recent (*ca.* 2010) introduction of Nine-banded Armadillo (*Dasypus novemcinctus*) on the island by local residents as an additional food source. Limited habitat destruction and alteration occurs on Cayos Cochinos, as palm tree fronds are harvested for thatch roofs (Wilson and Cruz-Diaz 1993). Though the iguanas on Cayos Cochinos face some level of threat from habitat destruction and harvesting, it is the restricted range (2.2 km^2) that amplifies the potential severity of these threats, and makes this population highly susceptible to local extinctions following hurricanes (Hayes et al. 2004). In addition, the limited range and observed higher population density could result in increased intraspecific interactions, in the face of more limited resources (e.g., Warner and Hoffman 1980; Jirotkul 1999; Abesamis and Russ 2005).

Though the potential range within the Valle de Aguán is substantially larger (> 1300 km^2; IUCN. 2011. *op. cit.*) than on Cayos Cochinos, this population faces more extreme threats. Large-scale habitat alteration and fragmentation, and harvesting of adults and eggs, threaten the population in the Valle de Aguán (IUCN. 2011. *op. cit.*). In the 1970s land conversion for agriculture began in this region. The impacts of this range from small scale clearing for cattle, to a large and expanding banana plantation owned by the Dole Fruit Company, where optimal habitat is continually cleared and pesticides are used. The exact amount of land conversion is unknown, but it appears that more than 50% of the habitat has been affected to some degree (Stesha Pasachnik, pers. obs.).

Interview data from the Valle de Aguán show that 84% of the community consumes *C. melanosterna* on a regular basis, and 60% prefer to eat gravid females due to the additional protein and the idea that eggs are medicinal (Pasachnik et al., unpubl. data). There is even an annual festival that celebrates the consumption of this species. Iguanas are also captured in this area for exportation to the illegal pet trade (Pasachnik and Ariano 2010). Although harvesting is officially prohibited, there is little to no enforced protection for this species within the area. There are no objective estimates for the past and current population size within this area; however, interviews indicate there has been a dramatic decrease in iguanas over the last 20 years (Pasachnik et al., unpubl. data). Feral mammals (dogs, cats, rats, goats, cows) do occur in this region, and to a larger extent than on Cayos Cochinos.

Given that there is considerable variation in the nature of threats faced and the level of protection afforded between the Valle de Aguán and Cayos Cochinos ESUs, understanding how these may be differently affecting the biology of the populations is important. It has been shown that these populations are genetically distinct, corresponding to ecologically unique habitats (Pasachnik et al. 2011); however, very little is known concerning the basic biology of the species. For the first time we evaluate aspects of the natural history of *C. melanosterna* over the entirety of its range, across both ESUs. Specifically our objectives were to examine differences in: (1) body size; (2) demography; and (3) body condition across ESUs. This information is vital in understanding the status of the species as a whole and in the construction of a comprehensive conservation and management plan that focuses on each ESU separately.

MATERIALS AND METHODS

Study sites.—*Ctenosaura melanosterna* inhabits tropical and subtropical dry forests and scrubland from 0–250 m above sea level (Holdridge 1967; Dinerstein et al. 1995; Wilson and McCranie 2004). The distribution of *C. melanosterna* within the Valle de Aguán and the corresponding habitat characteristics have been surveyed as part of a concurrent study (Pasachnik et al., unpubl. data). The dominant plant species are *Acacia riparia* (Leguminosae), *Opuntia* sp., *Stenocereus* sp. (Cactaceae), and to a lesser extent *Hematoxylum brasileto* (Caesalpiniaceae). All of these plants are included in the diet of *C. melanosterna*, and many also provide retreat sites for the species (Pasachnik et al., unpubl. data). The average height of the maximum emergent tree is 12 m and the average height of the canopy is 5 m. Deforestation, as well as soil, and water contamination are very high in these areas due to local

agricultural activity associated with cattle farming and a Dole banana plantation (Pasachnik et al., unpubl. data).

Habitat characteristics for Cayo Menor were reported by Bermingham et al. (1998). The dominant vegetation type is oak forest, which is estimated to cover approximately 50% of the island and be made up of at least 90% *Quercus oleoides* (Fagaceae). The understory consists of *Calliandra* (Fabaceae-Mimosoid)*, Connarus* (Connaraceae), *Alibertia edulis* (Rubiaceae), *Cupania* (Sapindaceae), and *Ouratea* (Ochnaceae). The oak trees range in size from 5–10 m in the windier areas of the island, to 35 m tall along some of the ridges. The hollow trunks of these trees provide retreat sites for iguanas. Other habitat types include mixed forests, palm groves, and mangroves (*Conocarpus erectus,* Combretaceae). Though this survey was only conducted on Cayo Menor, Cayo Mayor is ecologically similar (Wilson and Cruz Diaz 1993).

In this study we evaluated individuals from throughout the potential range in the Valle de Aguán as well as from the two primary populations within Cayos Cochinos (Cayo Menor and Cayo Mayor). Thus our sampling efforts correspond to the two ESUs that have recently been described (Pasachnik et al. 2011) and allow us to address the observed differences in threats between the ESUs. Because this is an endangered species, we will refrain from references to specific localities; however, legitimate researchers can acquire this information by contacting the authors.

Data collection.—We captured 522 adult and subadult *Ctenosaura melanosterna* on Cayos Cochinos, Honduras from 2007 to 2011 and within the Valle de Aguán, Honduras from 2006 through 2009. We conducted fieldwork primarily in the summer months across years. We captured individual lizards using noosing poles, traps, nets, and hand capture. We measured snout-vent length (SVL; to 0.1 cm) and tail length (TL; to 0.1 cm) using a tape measure and total body mass (BM; to 0.5 g) using balances or hanging Pesola scales. We determined sex based on external morphology (e.g., femoral pores and dorsal crest scales) and cloacal probing. To avoid resampling over time, we uniquely marked each individual. We marked all individuals on the mainland with a unique set of toe clips, and bead tags (Rodda et al.

1998) for permanent identification. On Cayos Cochinos, we permanently marked adults with passive integrated transponders (PIT) and small subadults with toe clips, except in the last season of sampling when we also added bead tags to adults for permanent identification. We also temporarily marked captured individuals with non-toxic paint for quickly identifying previously captured individuals. Processing lasted no more than 15 min and we released all individuals at the site of capture upon completion of data collection.

Statistical analyses.—Based on research on *Ctenosaura bakeri* (Gutsche and Streich 2009), we considered all individuals with SVL ≥ 15.0 cm to be adults for both sexes, as this was the most appropriate data available for size at maturity. We examined the effect of ESU (island or mainland) and sex on mass and SVL using a two way ANOVA. We compared SVL and mass between males and females within each ESU using t-tests. We examined size class distribution, sex ratio, and tail break frequency (TBF) between the two ESUs using Pearson's contingency analysis. When examining size class distribution, we included both subadults (10.0–14.9 cm) and adults in the analysis to take into account possible variation in size of maturity. We examined sexual size dimorphism in the relationship of TL to SVL using ANCOVA, with TL and SVL log-transformed to linearize the relationship. We compared the relationship of TL and SVL between populations for each sex separately in the same manner. For all analyses including TL, only complete tails were included. We calculated the body condition index (BCI) as the residual of the relationship of mass to SVL, following log-transformation. We compared the BCI among sexes and populations using ANOVA. We present all averages ± 1 SE. We performed all statistical analysis using JMP 7.0 (SAS Institute, Durham, North Carolina, USA) with a significance level of $\alpha = 0.05$.

RESULTS

Ctenosaura melanosterna male SVL was greater than female SVL ($F_{1,1} = 7.10$, $P = 0.008$; Table 1) in both populations and the island population was longer than the mainland population ($F_{1,2} = 15.35$, $P < 0.001$; Table

TABLE 1. Average and maximum snout vent length (SVL), mass, and standard errors for adult *Ctenosaura melanosterna* by sex from Valle de Aguán and Cayos Cochinos, Honduras.

		Average SVL (cm)	Max SVL	Average mass (g)	Max Mass
Cayos Cochinos					
	Male	24.38 (± 0.42)	32.2	579.5 (± 30.0)	1415
	Female	21.63 (± 0.24)	27.4	388.4 (± 13.3)	817
Valle de Aguán					
	Male	19.76 (± 0.77)	28.0	298.6 (± 41.5)	729
	Female	18.69 (± 0.53)	21.4	231.8 (± 19.8)	385

1) with no significant interaction ($F_{2,2} = 0.76$, $P = 0.468$). Males were also heavier than females ($F_{1,1} = 13.34$, $P < 0.001$; Table 1) in both populations and island animals were heavier than mainland animals ($F_{1,2} = 12.69$, $P < 0.001$; Table 1) with no significant interaction ($F_{2,2} = 1.85$, $P = 0.159$). The mainland population had more than expected individuals in the smaller size classes than the island population, which had more than expected larger individuals ($\chi^2 = 16.0$, $P = 0.003$; Fig. 1). The sex ratio (M:F) of the mainland population (1:0.56) was significantly more male-biased than the sex ratio of the island population (1:1.4; $\chi^2 = 7.38$, $P = 0.007$).

There was no significant difference in the relationship of TL to SVL between males and females for either the island population ($F_{1,1} = 2.31$, $P = 0.131$) or the mainland population ($F_{1,1} = 2.09$, $P = 0.163$). However, TL of adults was significantly longer relative to SVL on the island than the mainland in both males ($F_{1,1} = 48.20$, $P < 0.001$; Fig. 2) and females ($F_{1,1} = 65.04$, $P < 0.001$; Fig. 2b). There was no difference in TBF among island males (51.9%), island females (43.5%), mainland males (32.0%), or mainland females (35.7%) when analyzed together ($\chi^2 = 4.84$, $P = 0.19$) or separately by sex ($\chi^2 = 0.67$, $P = 0.41$) or population ($\chi^2 = 2.90$, $P = 0.09$). There was no effect of sex or population on BCI in *C. melanosterna* ($F_{3,325} = 0.22$, $P = 0.89$).

DISCUSSION

Ctenosaura melanosterna is a highly threatened species, in which two ESUs face different levels and types of threats. Our results show that the differences in poaching pressure can be observed through evaluating the morphology and demography between populations. Disparities in habitat modification, however, are not reflected in the characteristics we measured. Lastly, the

restricted range of the Cayos Cochinos population may be affecting the demography of that population.

Our morphometric analyses indicate that adult males are larger than females on Cayos Cochinos, which is consistent with the other species in this clade (Pasachnik et al. 2012; IUCN. 2011. *op. cit.*) and within the Iguaninae in general (Wikelski and Trillmich 1997; Beovides-Cases and Mancina 2006). However, there was no difference in size between males and females on the mainland, and individuals from the island population are larger on average than those from the mainland. We also found that larger individuals on the mainland were less represented than on the islands. These results suggest that the larger mainland individuals of both sexes are being harvested, which is consistent with the higher poaching pressure than is known to exist on the mainland.

The differences in sex ratio observed between populations suggest that there is not only more poaching occurring on the mainland, but that it is likely female biased. The female biased sex ratio for the protected island population was expected, as it is common among similar species in stable situations (1 male: 1.6–2.5 females in *C. similis* [Fitch and Henderson 1977], *Iguana iguana* in Colombia [Munoz et al. 2003], and *C. oedirhina* [Pasachnik, in press]). These results are consistent with interview data gathered from locals, indicating that gravid females are preferred for consumption (Pasachnik et al., unpubl. data). A reduction in adult females (particularly large females) can have severe repercussions for yearly reproductive output and the overall stability of the population, as has been noted for other iguanas (e.g., Faria et al. 2010).

The smaller body size, male biased sex ratio, and greater representation of smaller size classes observed in the Valle de Aguán may demonstrate the effects of selective poaching for larger individuals, particularly gravid females. However, they may also represent long evolved differences between the two ESUs or directional selection for earlier first reproduction and smaller body size on the mainland. Selective harvesting has been shown to result in directional selection against the desired trait within the population (Mysterud 2011). Evidence of selection for earlier first reproduction and smaller overall size has been observed in a variety of taxa (i.e., Platt and Thorbjarnarson 2000; Conover and Munch 2002; Olsen et al. 2004; Owens and Owens 2009).

Though there are substantial differences in the amount of habitat destruction between the populations, with the mainland suffering more severely, these are not reflected in the health of the mainland population using the characteristics measured herein. As other studies have shown, an increase in habitat destruction can lead to a decrease in the body condition of individuals (e.g., Amo et al. 2007; Brodeur et al. 2011). However, the BCI of
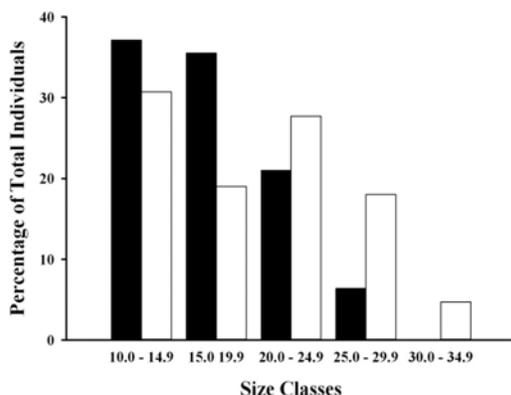
FIGURE 1. Size class distribution (cm) of *Ctenosaura melanosterna* from Valle de Aguán (black bars) and Cayos Cochinos (white bars), Honduras.
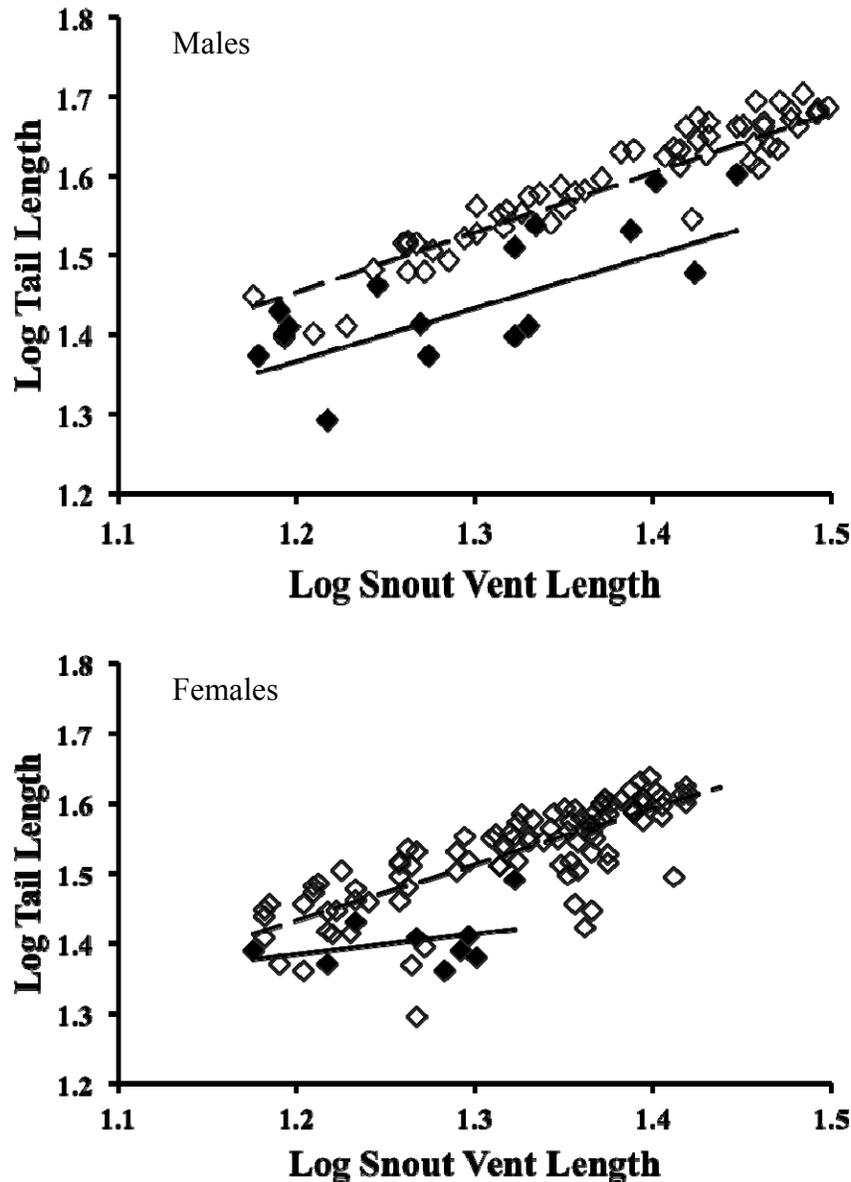
FIGURE 2. Relationship between log-transformed snout-vent length and log-transformed tail length for adult *Ctenosaura melanosterna* males (top) and females (bottom) with full tails from Valle de Aguán (black diamonds; solid line) and Cayos Cochinos (open diamonds; dashed line), Honduras.

the mainland population was not different from that of the more pristine, island population.

The restricted range of the island population makes it more susceptible to extirpation following hurricanes as has been shown by Hayes et al. (2004). This small range, however, may also intensify the effects of certain threats. Our findings of fewer than expected small size class individuals on the islands may be indicative of increased intraspecific interactions within this population, where young individuals are faced with increased competition and/or aggression from larger individuals (Choquenot 1991). In addition, the high

TBF observed in both males and females on the island relative to the mainland may be suggestive of increased intraspecific aggression, such as territoriality (Knapp 2000). However, the degree of TBF observed across sexes and populations indicates that this species is highly territorial in general (Hayes et al. 2012). Though feral mammal predation may be a factor in both cases, the trends are the opposite of what would be expected given that the mainland population is subjected to many more predators. Further studies are needed to address these issues.

Our finding of shorter tails on the mainland relative to the island may indicate increased terrestriality on the mainland, particularly given the observed differences in habitat. Tails have been shown to function as a balancing organ (Ballinger 1973), which has added importance for arboreal lizards. Jaksic et al. (1980) found that tail length was longer in climbing *Liolaemus* lizards, while shorter in those that are ground dwelling. The islands are characterized by tall oak forest, whereas shorter Acacia scrub trees and cacti characterize the mainland. Field observations indicate that iguanas from the island take advantage of this enhanced arboreal habitat. Previous genetic work on these ESUs also demonstrates evidence in support of adaptive differences between the populations (Pasachnik et al. 2011). Additional data is needed to further elucidate this finding.

Understanding the effects of demonstrated threats on a species is vital to conservation. This study allowed us to evaluate the potential consequences of threat pressure on the morphology and demography of a given species across populations with different threat levels and types. Additionally, it provided a baseline understanding of the biology of the species for future comparison in the event that these threats continue or change. Annual monitoring of these populations and increased protection of the mainland in particular is strongly recommended.

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