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DISTRIBUTION AND NATURAL HISTORY OF THE CAMPECHE SPINY-TAILED IGUANAS (*CTENOSAURA ALFREDSCHMIDTI*)

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Abstract.—**México has one of the greatest reptile diversities of any country in the world, with greater than 50% of species being endemic. Here we present information on the distribution and natural history of the Campeche Spiny-tailed Iguanas, *Ctenosaura alfredschmidti*, along a 70 km transect in southern Campeche, México. We observed 33 and captured 20 (16 adults and four juveniles) of those individuals for use in our analyses. Iguanas were captured primarily from *Haematoxylum* sp. trees at heights between 0.5 and 6.0 m. The sex ratio in this area was 1 M:2.2 F. There was no significant difference in snout-vent length between males and females. However, males were significantly heavier, had significantly longer tibias, and larger heads than females. We observed seven to ten femoral pores on each hind leg of adult *C. alfredschmidti*, with those of the males being more conspicuous than those of the females. The majority of iguanas were observed in lowland deciduous forest habitat, at elevations between 140 and 282 m. Fragmentation and habitat modification was evident across the study area. We estimated approximately 5.1 *Ctenosaura alfredschmidti* individuals/ha in a 1.68 km^2 area across the transect, although abundance is likely under-represented due to the secretive nature of this species. The Biosphere Reserve of Calakmul may serve as a conservation management area for the species. We recommend the status of this species be updated and be protected under Mexican law.**

***Resumen*.—México tiene una de las mayores diversidades de reptiles en el mundo, más del 50% de las especies son endémicas. Presentamos información sobre la distribución y la historia natural de las Iguanas de Cola Espinosa de Campeche, *Ctenosaura alfredschmidti*, a lo largo de un transecto de 70 kilómetros al sur de Campeche, México. Observamos 33 y capturamos 20 individuos (16 adultos y cuatro juveniles) para nuestros análisis. Las iguanas fueron capturadas principalmente en árboles de *Haematoxylum* sp., en alturas entre 0.5 y 6.0 m. La proporción de sexos fue 1 M:2.2 H. No hubo diferencia significativa en la longitud hocico-cloaca entre machos y hembras; sin embargo, los machos fueron significativamente más pesados, con tibias significativamente más largas y cabezas más grandes que las hembras. Observamos de siete a diez poros femorales en cada pata trasera de los adultos de *C. alfredschmidti*, en los machos más visibles que en las hembras. La mayoría de las iguanas se observaron en hábitat de bosque caducifolio de tierras bajas, a elevaciones entre 140 y 282 m. La modificación y fragmentación del hábitat fue evidente en toda el área de estudio. Estimamos unos 5.1 individuos/ha de *Ctenosaura alfredschmidti* en un área de 1.68 km^2 a través de nuestro transecto, aunque la abundancia está probablemente subrepresentada debido a la naturaleza secreta de esta especie. La Reserva de la Biosfera de Calakmul puede servir como área de manejo y conservación para la especie. Recomendamos actualizar el estado de esta especie e incluir su protección por las leyes mexicanas.**

Key Words.—biology; distribution; endemic; habitat; natural protected area; México

INTRODUCTION

México is second only to Australia in reptile species richness (P. Uetz. 2013. The Reptile Database. Available from http://www.reptile-database.org [Accessed 3 November 2014]) with 57% of Mexican reptile species being endemic to the country (Flores-Villela and García-Vázquez 2014). In recent decades, various new reptile taxa have been described in México (Dixon and Tipton 2004; Flores-Villela and Canseco-Márquez 2004; Liner 2007; Bezy et al. 2008; Campbell and Flores-Villela 2008; Flores-Villela and Smith 2009; García-Vázquez et al. 2010; Woolrich-Piña and Smith 2012; Bryson et al. 2014). The high species richness holds true for specific groups of reptiles as well, including iguanas. Of the 19 species of true iguanas in México (Iguaninae), 14 (73.6%) are endemic. The spiny-tailed iguanas (*Ctenosaura*) follow a similar trend, with nine of the 11 (81.8%) species occurring in México being endemic (ITWG this volume).

Mexican regulations list seven of the 11 species of *Ctenosaura* as endangered (*C. defensor*), threatened (*C. pectinata*, *C. oaxacana*, *C. similis*, and *C. clarki*), or with special concern ("sujeta a protección especial", *C. acanthura* and *C. hemilopha*). The latter refers to those species that could be threatened, and where recovery and conservation of their populations is promoted (NOM-059-SEMARNAT-2010: NORMA Oficial Mexicana, Protección ambiental-Especies nativas de México de flora

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y fauna silvestres-Categorías de riesgo y especificaciones para su inclusión, exclusión o cambio-Lista de especies en riesgo). The remaining species of *Ctenosaura* (*C. conspicuosa*, *C. macrolopha*, *C. nolascensis*, and *C. alfredschmidti*) have not yet been considered for protection under Mexican regulations, due primarily to the fact that little information exists regarding them. In order to better understand the status of these species, update legislation, and create proper management plans, additional information must be gathered.

The Campeche Spiny-tailed Iguana (*Ctenosaura alfredschmidti*) is one such species that is missing vital biological information. The species was described in 1995 from east of Escárcega (Köhler 1995) and later reported from Calakmul, both in southern Campeche, México (Calderon et al. 2003). Though this species has been reported from northern Guatemala (Radachowsky et al. 2003), it is now understood that this was actually *C. defensor* (ITWG this volume). Thus, this species is endemic to the southern region of Campeche, México. The adults are grey-green in color with conspicuous black markings on the back and sides of the abdomen, reddish markings posterior to the black markings on the abdomen, and reddish markings on the back of the neck and throat (Köhler 1995).

Very little additional information is known concerning this species. It is considered Near Threatened according to the IUCN Red List of Threatened Species, though the assessment states that the species nearly meets the criteria to be listed as Critically Endangered and calls for additional information to be gathered (Köhler 2004). In the decade since the Red List assessment, no studies have been conducted to generate these data concerning distribution and natural history. The local government of Campeche promotes and supports studies of reptile species at risk, such as turtles (Berzunza Chio 2010) and crocodiles (Padilla et al. 2010), however iguanas have largely been ignored.

In an effort to collect these vital data for *C. alfredschmidti* we conducted opportunistic visual encounter surveys in southern Campeche, México, between February and July 2010. Our goal was to elucidate aspects of morphology and habitat use. Data presented here will aid in updating the protected status of this species under Mexican law, and in constructing proper conservation management proposals for the species.

Materials and Methods

Study site.—Our study site consisted of 1.68 km^2 in southern Campeche, México, on the Yucatán Peninsula near the communities of Escárcega, Matamoros, Libertad, Justicia Social, Silvituc, Constitución, Xpujil, and Calakmul (Fig. 1). The area is characterized by low elevation (< 300 m), an annual rainfall of 100–1,200 mm (Rebolledo Vieyra 2010), and two climatic variants from west to east. Agro-climatic variant type Aw2 is warm and humid with summer rains and mean annual temperature of 22–26° C, occurring near the town of Nueva Conhuas in the western portion of our study area. The second agro-climatic variant, type Aw1(x'), is characterized as having little rain throughout the year, and has a greater influence near Xpujil (Mendoza Vega and Kú Quej 2010) in the eastern portion of our study area. Much of the habitat in this general area is disturbed due to livestock and agricultural fields (beans and corn), new roads, and electric transmission lines. However the area within the Calakmul Biosphere Reserve represents more pristine habitats, including the Balam-ku and Balam-kin Reserves (Lugo-Hubp et al. 1992; Bautista et al. 2005). The predominant vegetation in the area is lowland deciduous forest, tropical low flooded forest, secondary vegetation, farming, and uncovered soil (Palacio et al. 2002; Colchero et al. 2005; Noriega-Trejo and Palacio Aponte 2010) (Fig. 1).

Data collection.—We searched for iguanas, exploring all microhabitats (tree holes, stumps, and logs) along a 70 km long by 24 m wide transect (Fig. 1). We conducted our surveys from February through July 2010. For two weeks each month we searched for eight hours a day, between 0800 and 1600. We sampled the entire transect area twice. We surveyed 24 km along the distance of the transect every month, surveying the same section for two consecutive months. Our total sampling effort was 1,344 person-hours.

We marked each individual by injecting a microchip subcutaneously in the mid-dorsum (RFID, 12 mm, Trovan®, Trovan Ltd., United Kingdom). We photographed each individual before and after capture, and captured all iguanas by hand. We used the initial photographs to identify color patterns and unique marks for future recognition using binoculars (8 x 40). We did not resight or recapture any iguanas. We measured snout-vent length (SVL) to the nearest 0.1 mm, and tail length (TL), tibia length (TBL), head length (HL), and maximum head width (HW) to the nearest 0.1 mm using a tape measure and vernier calipers. We measured head width at the widest part of head, immediately posterior to the eyes, and head length from the tip of the snout to the posterior end of the jaw. We measured total mass (TM) to the nearest 0.1 g using Pesola® spring scales (PESOLA AG, Baar, Switzerland). We determined sex based on external morphology and cloacal probing. We released iguanas at the site of capture after processing. At each site we documented the height of the capture point of each iguana, habitat type, and ambient temperature in the shade approximately 1.5 m off the ground, using a manual weather station (Kestrel 4000, KestrelMeters.com, Birmingham, Michigan, USA).

We determined the difference between juveniles and adults based on the descriptions for *C. defensor* (Lee 2000) and *C. clarki* (Gicca 1982; Pérez-Ramos and Saldaña de la Riva 2002), which are closely related

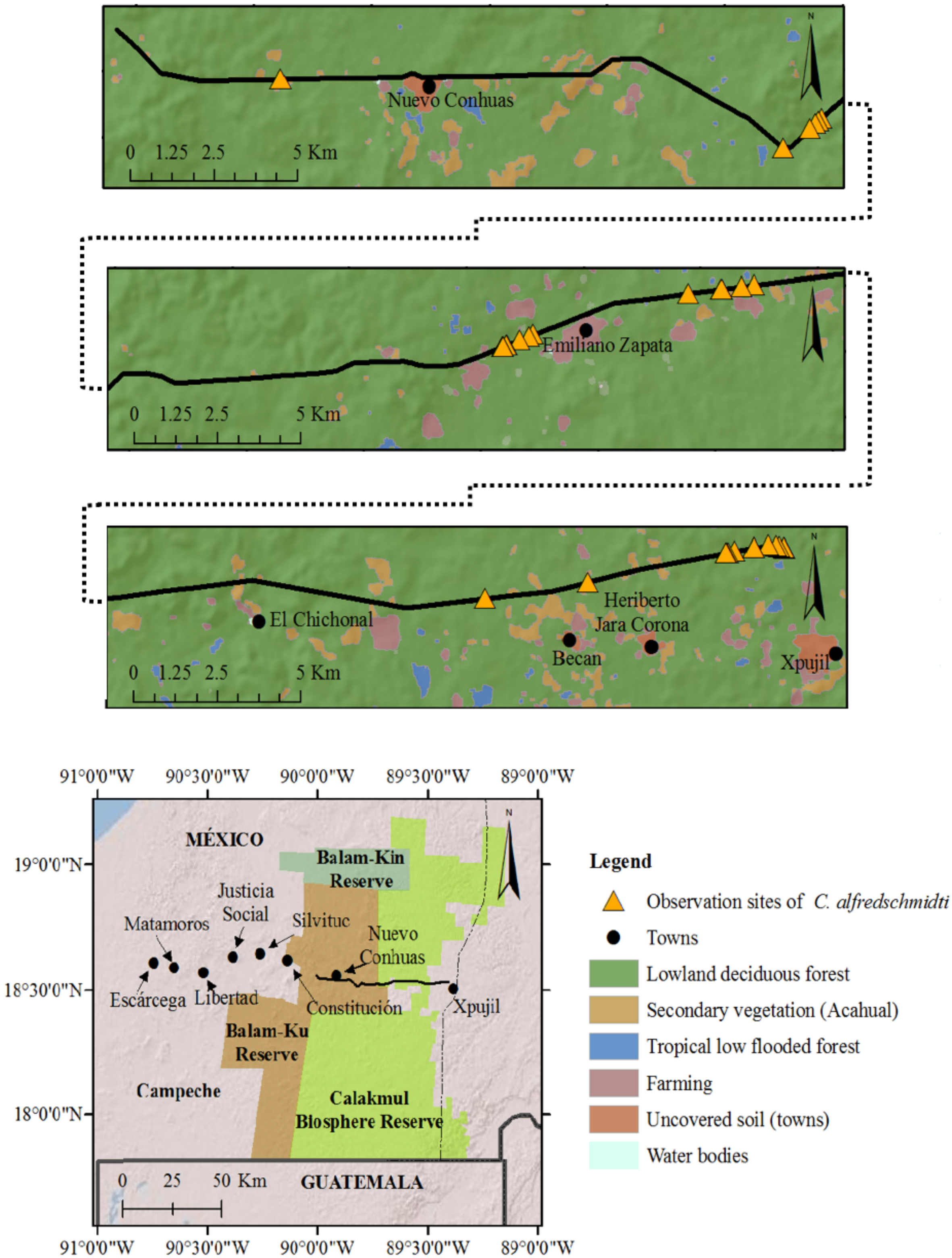

FIGURE 1. Location of transect (black line) and vegetation types along the transect used to survey for *Ctenosaura alfredschmidti* in Campeche, México. The Calakmul Biosphere Reserve is represented by all highlighted areas in the lower map, with the two sections of smaller specific reserves highlighted in two different colors. The upper maps zoom into the transect area and run in consecutive order from west to east moving down the page.

(Köhler et al. 2000; Köhler et al. 2003) and have a similar body size (SVL). We considered individuals with SVL > 90.5 mm to be adults. We identified gravid females by palpating the abdomen of those females that were visibly more robust than others. Developing eggs in the abdominal cavity were clearly identifiable.

Statistical analyses.—We used both parametric and nonparametric tests, depending on data distribution. Assuming a sex ratio of 1:1 we calculated differences between the expected value and the observed using a chi-square test. We compared SVL, HL, HW, TBL, and TM between males and females using *t*-tests. Gravid females were not used in TM analyses. We did not make comparisons of TL due to the high percentage of tail breaks that we encountered. We also compared the number of femoral pores between males and females using a Mann-Whitney U test. Means are presented ± 1 SD. We performed all statistical analysis using Statistica v7.0 for Windows (StatSoft Inc., Tulsa, Oklahoma, USA) with an alpha of 0.05.

Results

We observed 33 individuals in 1.68 km^2 and captured 20 of those, including 16 adults (five males and 11 females) and four juveniles (juvenile mean SVL = 69.8 ± (SD) 14.1 mm (range, 51.9–90.5 mm)). The sex ratio was significantly female-biased (1 M:2.2 F, $\chi^2 = 128.79$, $P < 0.001$). Males were not significantly longer than females ($t = -1.06$, $P > 0.05$), but had significantly longer tibias ($t = -2.56$, $P = 0.022$), and longer ($t = -4.08$, $P = 0.001$) and wider heads than females ($t = -3.61$, $P = 0.003$) (Table 1). Given the high incidence of regenerated tails in adults (80% males and 82% females), TL comparisons were not made. The tail length observed in two adult females that did not have regenerated tails was 120.5 mm and 125.3 mm, and in one adult male was 153.6 mm. Four of the females captured (one on 4 February 2010, two on 22 February 2010, and one on 5 April 2010) were gravid, therefore we did not include them in the TM analysis. Males were significantly heavier than the remaining seven females ($t = -2.15$, $P = 0.050$; Table 1). No difference was found in the number of femoral pores between males and females (left: $U = 42.0$, $P = 0.78$; right: $U = 39.5$, $P = 0.56$). Between seven and 10 femoral pores were found on each leg (mode = eight pores), and the pores in males were more conspicuous than females (Fig. 2).

Thirty-two of the 33 observed iguanas were in lowland deciduous forest that is susceptible to flooding. The remaining individual was recorded from secondary vegetation. No iguanas were observed in farming areas. We observed all iguanas on wide branches (approximately 20 cm in diameter) while basking. Observations occurred at elevations between 140 and 282 m (mean = 222.5 ± 41.7 m), on trees at heights between 0.5 and 6.0 m (mean 2.6 ± 1.6 m); 36.3% (n = 12) of individuals were found in *Haematoxylum* sp. trees (*H. campechianum* and *H. brasiletto*) (Fig. 3) and 15.2% (n = 5) in felled logs. Between one and two individuals were found in *Cordia dodecandra*, *Thouinia paucidentata*, *Forchhammeria pallida, Caesalpinia gaumeri*, *Vitex*

TABLE 1. Mean and standard deviations of capture height, snout-vent length (SVL), tibia length (TBL), head length (HL), head width (HW), and total mass (TW) in adult *Ctenosaura alfredschmidti* by sex from Campeche, México. Ranges are in parentheses.

	Female (*n* = 11)	Male (*n* = 5)	*t*-value	df	*P*
Capture height (m)	2.7 ± 1.9 (0.6–6.0)	1.9 ± 1.1 (0.8–3.5)	0.84	14	0.414
SVL (mm)	147.5 ± 17.7 (120.3–174.4)	156.7 ± 11.4 (142.4–170.0)	-1.06	14	0.306
TBL (mm)	24.5 ± 2.9 (20.3–35.0)	28.3 ± 2.1 (24.7–30.3)	-2.56	14	0.022
HL (mm)	32.1 ± 3.9 (25.9–39.9)	40.9 ± 3.9 (35.6–46.6)	-4.08	14	0.001
HW (mm)	21.3 ± 1.9 (19.1–23.6)	25.8 ± 2.9 (21.4–29.0)	-3.61	13	0.003
TM (g)	107.4 ± 26.9 (60.0–148.0)	143.0 ± 36.7 (105.0–188.0)	-2.15	13	0.050

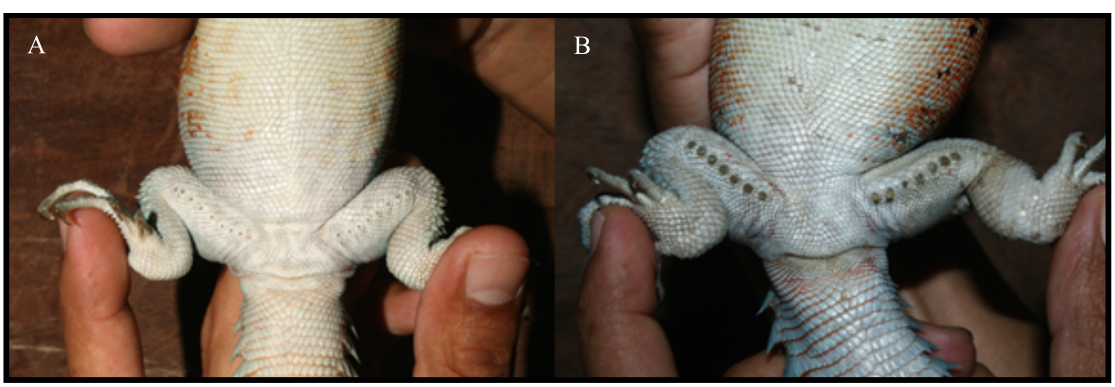

FIGURE 2. Differences in femoral pores between (A) female and (B) male *Ctenosaura alfredschmidti* from Campeche, México. The number or pores is consistent across sexes, but the pores in females are rudimentary. (Photographed by Ahmed Bello).

gaumeri, *Jacquinia macrocarpa*, and *Manilkara zapota*. The remaining iguanas were observed in unidentified trees. Mean perch height was 2.8 ± 2.3 m (range, 0.6–6.0 m) in lowland deciduous forest; the one individual recorded in secondary vegetation was at a perch height of 0.5 m. Gravid females were captured in lowland deciduous forest (three individuals on *Haematoxylum campechianum* and one on *Cordia dodecandra* trees at heights between 0.9 and 5.8 m). We captured iguanas when the average temperature was 33.6° C (27.2–39.7° C) and the average humidity was 53% (36.3–85.7%).

Discussion

Male *Ctenosaura alfredschmidti* were not longer than females, unlike what has been reported for other species in the genus such as: *C. clarki* (Duellman and Duellman 1959), *C. similis* (Fitch and Henderson 1977), *C. pectinata* (Köhler and Streit 1996; Arcos-García et al. 2005), *C. melanosterna* (Pasachnik et al. 2012a), *C. bakeri* (Pasachnik et al. 2012b), and *C. oedirhina* (Pasachnik 2013). *Ctenosaura alfredschmidti* males do however have larger heads than females as has been reported in other iguaninae: *Cyclura rileyi* (Carter and Hayes 2004), *Ctenosaura bakeri* (Gutsche and Streich 2009), *Brachylophus vitiensis* (Morrison et al. 2013). Sexual size dimorphism of the head could be related to a social mating system (Vitt and Cooper 1985; Hews 1990) or sexual selection, for example, larger heads may have an advantage in male-male combat (Carothers 1984; Gier 1997).

The frequency of broken tails observed in *C. alfredschmidti* was extremely high (~ 80%), when compared to congenerics: < 50% in *C. oedirhina* (Pasachnik 2013) and < 40% in *C. bakeri* (Pasachnik et al. 2012b). In addition, there was no sex bias in tail breaks, as there was in *Cyclura cornuta*, with 46% and 27% for males and females, respectively (Pérez-Buitrago et al. 2010). The high degree of tail autotomy could be indicative of predation attempts (Hayes et al. 2012), or allude to a high level of conspecific aggression (Pérez-Buitrago et al. 2010; Davis et al. 2011). Since this species is not hunted for food, human-influenced events are unlikely to be the cause of tail breaks, although this cannot be completely ruled out as humans may attempt to harm this species out of fear.

The female biased sex ratio (1:2.2) observed herein may be an indication that the population in this area is stable, or at least devoid of human hunting pressure as has been confirmed through conversations with locals. A female biased sex ratio is consistent with that found in other stable iguana populations: *C. similis* (1:1.6, Fitch and Henderson 1977), *C. melanosterna* (Cayos Cochinos ESU, 1:1.4, Pasachnik et al. 2012a), *C. oedirhina* (1:1.6, Pasachnik 2013), and *Iguana iguana* (1:2.5, Muñoz et al. 2003). In areas where hunting pressure is known to exist, the reported sex ratio is male biased as gravid females are often targeted for their eggs (Faria et al. 2010; Pasachnik et al. 2012a, b).

The rough density estimate that can be made from our data may also allude to the stability of the population. In the 1.68 km^2 surveyed, 33 observations of individual iguanas were made, or 5.1 individuals/ha. In addition, it can be assumed that the detection rate is low based on the secretive nature of this species. At the upper-end of what has been documented for ctenosaurs, Rioja et al. (2012) reported values for *C. oaxacana* of up to 33.7 individuals/ha in México, and Gómez-Mora et al. (2012) reported values up to 12.3 individuals/ha for *C. pectinata* in Buenavista, Michoacán, México. In comparison, *Ctenosaura quinquecarinata* were estimated at 0.93 individuals/ha on a wildlife refuge in Nicaragua (Robleto 2010), values of *C. similis* ranged from 0.6 to 3.1 individuals/ha in Zamorano, Honduras (Terán Flores 2006), and *C. palearis* were estimated at 0.59 individuals/ha in the Motagua Valley, Guatemala (Cotí and Ariano-Sánchez 2008). Though additional surveys need to be conducted that focus specifically on population and density estimates, it is likely that the density estimates will still fall within the middle of the range of those that have been previously recorded. Habitat alteration (Fig. 4) is likely to be contributing to a reduced encounter rate.

The lowland deciduous forests of Campeche, México that is preferred by *C. alfredschmidti*, are currently undergoing modification to support an increasing human population. Campeche has the second highest level of deforestation in México, with 10.5% of deciduous and

Figure 3. Male *Ctenosaura alfredschmidti* basking in *Hemaetoxylum campechianum* tree within sub-deciduous low forest in Campeche, México. (Photographed by Ahmed Bello).

semi-deciduous forest lost (Instituto Nacional de Ecología y Cambio Climático. 2008. Cambio porcentual de la vegetación y uso del suelo 1976–2000. Available from http://www2.inecc.gob.mx/emapas/download/dinamica_1976_2000.pdf [Accessed 5 August 2013]). The primary crops are fruit trees, mainly *Byrsonima crassifolia*, corn, and other grains (Quintana-Morales 2014). The development of new roads and electric transmission lines also contributes to fragmentation of the habitat. This process creates edges with large numbers of felled trees where iguanas were found basking. However, iguanas in these areas are likely to have an increased predation risk given the increased exposure of the individuals.

The increase in crop production presents another possible problem for the iguanas with the corresponding pollution from hydrocarbons and agricultural pesticides. The bioaccumulation of this waste material is known to affect herbivores and insectivores (Morales-Rodríguez and Cobos-Gasca 2005) such as the iguanas. These compounds have been shown to affect reproduction and damage brain tissue in other species, as has been witnessed in the case of some birds and turtles in the Yucatán Peninsula (Morales Rodríguez and Cobos-Gasca 2005; Cobos Gasca et al. 2011).

Nevertheless, these forests still cover a large area, and although the iguanas appear to be represented in low numbers, they have been captured within the Biosphere Reserve of Calakmul (723,185 ha, one of the largest protected areas in México, Fig. 1), which may offer some protection for the long-term persistence of the species. This study provides basic information on *Ctenosaura alfredschmidti* and can be useful for structuring conservation strategies for this species. Long-term monitoring studies focusing on nesting, demographics, foraging, home range, habitat use, and distribution are recommended, while they are still possible. In addition, genetic studies focusing on population structure across the range are vital to understanding the status of the species, particularly in the face of continuing fragmentation. Such studies are important, as environmental officials of the Mexican government (SEMARNAT) promote rescue and translocation programs of wildlife when governmental or private companies propose modification of the environment. In general, authorities should pay special attention to populations of Campeche Spiny-tailed Iguanas, and ensure that individuals are managed properly. Given the data we have presented and what is known about the forest modification in the area, we feel that *Ctenosaura alfredschmidti* should be protected by Mexican Law NOM-059 of SEMARNAT, due to its likely threatened status and potential for continual decline in the near future.

FIGURE 4. Evidence of habitat destruction in the *Ctenosaura alfredschmidti* study site, Campeche, México. (Photographed by Adolfo López Galindo).

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