IRCF

REPTILES & AMPHIBIANS

CONSERVATION AND NATURAL HISTORY

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DUSTIN C. SMITH

This juvenile female Giant Musk Turtle (*Staurotypus salvinii*) was recently discovered in Miami, Miami-Dade County, Florida (see article on p. 55).

RAFE BROWN

Hylarana tipanan was described in 2000, but the experts who describe biodiversity are disappearing (see commentary on p. 39).

DANIEL P. SCANTLEBURY

A distressed male *Sphaerodactylus leucaster* with the vertically elliptical pupil it shares with other nocturnal geckos (see article on p. 12).

ROBERT POWELL

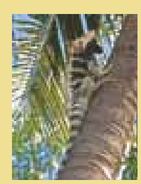
Melanistic Sombrero Ameivas (*Ameiva corvina*) occur only on the small isolated island of Sombrero, the northernmost of the Lesser Antilles. This individual had just excavated a beetle grub (see travelogue on p. 42).

GAD PERRY

Texas Horned Lizards (*Phrynosoma cornutum*) are popular with Texans who often bring them home. They regularly show up at the South Plains Wildlife Rehabilitation Center in Lubbock, Texas (see article on p. 18).

Front cover: Barry Brown

Teiid lizards (racerunners and whiptails) are typically not territorial, although males will fight for access to females and for other reasons we do not fully understand. These two male Curaçao Whiptails (*Cnemidophorus murinus murinus*) were so intent on each other that they tolerated a very close approach by the photographer. Look for an article by Gerard van Buurt about the teiid lizards of Aruba, Bonaire, Curaçao, and the nearby Paraguaná Peninsula of Venezuela in an upcoming issue of *Reptiles & Amphibians*.



Back cover: Stuart Brooker

An adult male Saint Lucia Iguana (*Iguana* cf. *iguana*) from near the nesting site at Louvet Estate on Saint Lucia's northeastern coast. This genetically unique population might be threatened by invasive non-native Green Iguanas (*I. iguana*) that are breeding in the dry and mesic forests around Soufrière in the southwest of the island. The most pressing concern is potential hybridization between individuals in the two populations, although competition between them could also pose a problem if they came into contact. See the article on p. 24.

IRCF REPTILES & AMPHIBIANS
CONSERVATION AND NATURAL HISTORY

TABLE OF CONTENTS

JOHN F. BINNS

The Grand Cayman Blue-fanned Anole (*Anolis conspersus*) is the only native anole on Grand Cayman. However, introduced Cuban Brown Anoles (*A. sagrei*) have forced *A. conspersus* to use higher perches in open habitats where both species occur.

A juvenile *Macrochelys temminckii* (also illustrated in Fig. 2) basking on a floating railroad tie at 0727 h. Note the leech occupying a space between the vertebral and right lateral keels.

Basking in the Alligator Snapping Turtle, *Macrochelys temminckii* (Testudines: Chelydridae)

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Photographs by the senior author.

Macrochelys temminckii is the largest freshwater turtle in North America, and is often considered one of the most aquatic species as well (Pritchard 1967). Only adult females are known to regularly leave the water, and then only to nest (Ernst and Barbour 1972, Zappalorti 1976, Pritchard 1989). Basking in this species was long thought to be non-existent or extremely rare (Brattstrom and Collins 1972, Ernst and Barbour 1972). Although some authors have suggested that aquatic basking occurs in this species (Zappalorti 1976, Howey and Dinkelacker 2009), no published reports describe such behavior. However, several publications describe aerial basking in *M. temminckii*, but each literature report consists of a single observation (Ewert 1976, Shelby and Jensen 2002, Farr et al. 2005, Selman et al. 2009, Thomas 2009, Selman and Willig 2010). Of the six reported instances of basking, one was a hatchling (42 mm, Shelby and Jensen 2002), three were juveniles (~100–200 mm CL; Ewert 1976, Thomas 2009, Selman and Willig 2010), and two were of adult sizes (~350–400 mm, Farr et al 2005; ~400–500 mm, Selman et al. 2009). One instance of basking was inferred from capturing a specimen in a basking trap (Shelby and Jensen 2002). In the other five cases in which basking was actually observed, three of the turtles appeared to have been basking for some time, as the animals were described as dry (Ewert 1976, Farr et al. 2005, Thomas 2009), but the maximum reported observation period lasted no longer than about 12 min (Farr et al. 2005). All six observations were associated with lotic habitats (creeks or rivers), with basking substrates including a fallen tree trunk, snags, and river banks. Where reported, turtles were resting on the basking substrate inclined at angles estimated at 30–60°, with the head pointed upslope (Ewert 1976, Farr et al. 2005, Selman et al. 2009). In one case, the animal's resting angle was not noted, but the snag to ascend to the basking spot was nearly vertical (90°) and involved climbing over an intervening obstacle (Selman and Willig 2010). The five recorded times for basking behavior were between 1000 and 1700 h.

During the 2009 field season, we observed two instances of aerial basking and one of aquatic basking, all involving juvenile *M. temminckii*. Observations were made at Black Bayou Lake National Wildlife Refuge, 11.5 km north of Monroe in Ouachita Parish, Louisiana. The centerpiece of the refuge is a large lake (~845 ha), which is a back swamp (Wang 1950) that has been dammed by a railroad line, and now has the water level controlled with a stop-log structure. Air temperatures were obtained from the nearest station in Ouachita Parish for the appropriate date and time (Weather Underground, http://www.wunderground.com).

While radio-tracking on Black Bayou Lake at approximately 1400 h on 9 March 2009, a juvenile *M. temminckii* (carapace length [CL] = 174.3 mm, weight = 1.04 kg) was observed with its head exposed above the water. The afternoon was sunny, with very little cloud cover. Upon closer inspection, the turtle was found to be floating above a bed of submerged aquatic vegetation composed primarily of *Egeria densa* (Brazilian Waterweed) and *Ceratophyllum demersum* (Coontail). The head and keels of the carapace were exposed above the water, where it remained for a period of ~5 min, with no indication that it was foraging. The turtle was captured by hand and brought to the lab for examination. It was identified by a PIT tag as a "head-started" juvenile from the 2004 year-class that we released on 12 June 2008. Water temperature at the time of capture was 21 °C and air temperature was approximately 27 °C. This observation matches well the

Fig. 1. Juvenile *Macrochelys temminckii* (A) basking on the end of a railroad tie in the shade of a Water Elm (*Planera aquatica*). The same individual (B) immediately after capture. Note the large leech attached to the carapace.

description of aquatic basking by Moll and Legler (1971). They described aquatic basking as behavior in which "turtles ... were motionless at the surface with limbs fully extended and part of the carapace out of the water," and went on to say that the most common sites for aquatic basking of Panamanian Sliders (*Trachemys venusta*) "were over beds of [a submerged aquatic plant] or near other mats of vegetation."

In the course of terrestrial nesting surveys along the railroad causeway in the northwestern corner of the lake, we observed a juvenile (CL = 190.2 mm, weight = 1.52 kg) on 20 April 2009 at 0900 h. It was resting on an old railroad tie among riprap at the margin of the lake, 29 cm above ground level. The wet turtle was sitting askew on the bank end of the railroad tie with a large leech on the right side of its carapace (Fig. 1). The railroad tie was inclined at ~12° into the water from the bank. Based on the animal's position and the wet trail it left on the tie, the turtle had to have climbed the bank and then the end of the railroad tie (~80–90°) to reach its location atop the high, out-of-water end. The turtle was positioned in such a way that it was resting at an angle near horizontal. The left hind leg was dangling in the air, but the right-side limbs were extended and in contact with the substrate; the head and neck were also extended and resting on the wood. The digits were not maximally abducted (spread apart). This turtle was observed for just a few minutes before being captured. When approached, the animal quickly dove into the water on the lake-side of the railroad tie. At the time of this observation conditions were clear and sunny, although the basking site was fully shaded by a small Water Elm (*Planera aquatica*). Air temperature at the time of capture was approximately 17 °C.

We found another basking *M. temminckii* during a terrestrial nesting survey along the lake margin on 29 April 2009. At 0720 h, a juvenile (carapace length ~140 mm) was observed on a railroad tie floating ~3 m from the shoreline (Fig. 2). As can be seen in the photograph, the tail extends straight behind the body, the right hind leg is minimally extended without abducted digits, the right forelimb is more fully extended, and all are in contact with the substrate. The head and neck are fully extended and the animal appears alert, possibly with the proximal portion of the neck resting on the substrate. The weathered railroad tie was horizontal, providing a 0° basking surface, and was located in the early morning shadows, not exposed to the sun. A leech was noted on the carapace, and the turtle was photographed and observed until 0730 h, at which time the observer (JLC) left the site. At approximately 0807 h, when the observer returned to the basking site, the individual was seen in the same position, and the carapace was drier, indicating that basking had continued in the meantime. In addition, the leech that had been observed on the carapace moved until it was out of sight (Fig. 2 insert), which fits with the idea that the drying of a turtle during basking would tend to cause leeches to release their hold (Pope 1939, Cagle 1950). The empty puparium and a newly emerged adult damselfly (Odonata: Zygoptera) are also visible in one of our photos, so the turtle had remained in the same position long enough to serve as a substrate for emergence by this aquatic insect. The first to last observations of this individual spanned 58 min. Air temperature was approximately 22 °C.

Our observations include the first specific instance of aquatic basking reported for the species, and two additional instances of aerial basking. Obbard and Brooks (1979) noted a preponderance of aerial basking in *Chelydra*, but the incidence of aquatic basking was as high as 16% of all basking observations for radio-telemetered individuals in their population. These are the only observations of basking *M. temminckii* that we have

Fig. 2. A second juvenile *Macrochelys temminckii* basking on a floating railroad tie. Note that the leech is moving across the vertebral keel at 0816 h. In the insert, the leech is no longer visible on the carapace at 0817 h.

made during 15 years of field work at this site by the senior author (1996–2010), so we are inclined to agree with the notion that basking occurs only rarely in this species (Ewert 1976). Obbard and Brooks (1979) noted among the reasons that basking might have been infrequently reported in *Chelydra serpentina* prior to their study was that individuals almost always bask alone on a particular object, as opposed to emydids, which are frequently found in large numbers on the same object or even stacked on one another. All reports of aerial basking *Macrochelys* are of single individuals, thus if the animals are wary, an individual could very easily slip into the water unnoticed. In addition, with respect to *M. temminckii*, the dark coloration of the carapace and soft parts would tend to be well camouflaged on most logs or other woody structures, and the rough texture of the shell and soft parts would tend to disrupt the outline of the turtle, both of which would complicate seeing an individual before it slipped into the water.

All reports of aerial basking in *M. temminckii* involve single individuals on a bank or wood substrate. In *C. serpentina* (its closest North American relative), Obbard and Brooks (1979) reported that 99% of 233 aerial basking observations involved a single turtle on a basking object. The posture assumed by the two aerial basking *M. temminckii* that we observed was similar to what Ewert (1976) described for *Chelydra*, in which the feet remain in contact with the basking object, rather than being fully extended in mid-air with the digits maximally abducted as is commonly seen with the hind limbs in emydids (Cagle 1950, Auth 1975). Obbard and Brooks (1979) reported seeing limbs extended with the webbing spread in *Chelydra,* but they did not quantify the incidence of the behavior; however, in their photo, the left hindlimb is not elevated above the substrate with the digits maximally abducted. Obbard and Brooks (1979) also noted that only about 5% of their *Chelydra* basking observations involved an on-shore basking substrate. With respect to *Macrochelys*, four of the aerial basking observations have involved basking substrates on the bank or a log attached to the bank, and four involved free-floating or fixed offshore objects.

With a total of nine basking observations for the species now, comparison with factors related to the appearance of the behavior may start to be made. Some explanations for basking are applicable only to adult turtles. Of the nine known instances of basking in *M. temminckii*, the majority of individuals were juveniles (7 of 9, including our 3 observations), so any association with maturation of ovarian follicles in females or warming by basking in the spring to enhance mating behavior (Obbard and Brooks 1979) could account for no more than a small fraction of the reported cases. A number of general explanations for basking behavior are available, including thermoregulation (Boyer 1965, Moll and Legler 1971, Obbard and Brooks 1979), vitamin-D synthesis (Pritchard and Greenhood 1968), drying of the skin and shell surface that could reduce ectoparasite and epizoophyte load (Pope 1939, Cagle 1950, Boyer 1965, Shelby and Jensen 2002), and as a response to illness or injury (Selman and Qualls 2009). The case of aquatic basking would seem clearly related to thermoregulation since it was exposed to full midday sunlight and is the earliest spring date recorded for basking when water temperatures were relatively low. Our other two observations both involved turtles in the shade, Ewert's (1976) observation was under a lightly overcast sky, and Thomas (2009) reported the individual he saw was in partial sunlight. Although most individuals that have been observed were exposed to sunny skies as one would expect of a turtle basking for thermoregulation, indirect ultraviolet light associated with vitamin-D synthesis could still reach a turtle under a cloudy sky or in the shade, but much less effectively than exposure to direct sunlight. Both of the aerial basking individuals we observed had large leeches on the carapace, and for one of the two, we were able to document that the leech released its initial hold and moved over time as the turtle's shell dried. This was similar to observations of *Graptemys* by Selman et al. (2008) and Selman and Qualls (2009); however, Thomas (2009) noted 100+ leeches were still attached to the juvenile he captured while basking.

Acknowledgments

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LAINE GIOVANETTO

Plethodon cinereus has a very large geographic range spanning most of the northeastern United States.

Sympatry between Two Wide-ranging Salamander Species

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Abstract.—Understanding how closely related species coexist remains a central problem in community ecology. Habitat characteristics, presence of predators and competitors, and frequency of disturbance all affect the geographic distribution of a species. *Plethodon cinereus* and *P. electromorphus* are two closely related and ecologically similar species that have a large geographic overlap in their distributions. In this study, I had two main goals. First, I wanted to determine how commonly sympatric locations occurred between these two species. To address this goal, I conducted landscape-scale surveys in areas that should contain sympatric locations based on their distributions. My second goal was to determine if the relative number of individuals of each species within sympatric locations was stable over time by monitoring four sympatric locations over three years. In addition, flooding occurred during one year of the study, impacting two of the four monitored sympatric locations; therefore, I wanted to examine whether this disturbance affected the salamander populations at those locations. This flooding event provided a rare opportunity to study the impact of flooding on terrestrial salamanders, a topic about which little is known. I found that sympatric locations occurred less frequently than expected by chance and that some sympatric sites seem to be relatively stable while at others, the relative population size of *P. cinereus* was increasing — and that this shift might be positively affected by flooding. While this study demonstrated that *P. cinereus* and *P. electromorphus* do not occur in sympatry as frequently as expected by chance, the cause for this result is unknown. The most likely factor is that the two species exhibit subtle habitat differences that have not yet been demonstrated. The interactions between *P. cinereus* and *P. electromorphus* are complex, and the patterns observed here could have been generated by any number of mechanisms. Further research on this system could clarify some of these remaining questions.

Understanding how closely related species coexist remains a central problem in community ecology. The amount of overlap between the geographic ranges of closely related species is thought to depend, in part, on the extent to which similar species share the same habitat requirements. Closely related species tend to overlap more than expected by chance, suggesting that species' distributions are more constrained by shared niche requirements and common ancestry than by competition (Harvey and Pagel 1991, Letcher et al. 1994). Conversely, niche similarity may lead to intense competition and eventual exclusion resulting in rare co-occurrence of the two species (Bowers and Brown 1982). The distribution of a species could be affected by any number of mechanisms that could include habitat characteristics and the presence of predators or competitors.

Interspecific competition and territorial aggression seem to be prevalent within the genus *Plethodon* (e.g., Jaeger 1970, Nishikawa 1985, Anthony et al. 1997, Marshall et al. 2004). In some instances, interspecific competition has limited the geographic ranges of competing species (Jaeger 1970, Hairston 1980, Arif et al. 2007) and has led to a variety of evolutionary consequences between sympatric species, such as character displacement (Adams and Rohlf 2000), competitive exclusion (Jaeger 1971, Myers and Adams 2008), and alpha-selection — intense interspecific aggression (Nishikawa 1987, Deitloff et al. 2009). Further, these effects appear to have shaped species distributions at a broad geographic scale, because patterns of community composition are consistent with what is predicted from competitive-based models of community dynamics (Adams 2007).

Fig. 1. Adult *Plethodon cinereus.*

Fig. 2. Adult *Plethodon electromorphus.*

Plethodon cinereus (p. 6 and fig. 1) has a very large geographic range spanning most of the northeastern United States; and, while the geographic range of *P. electromorphus* (Fig. 2) is much smaller, this species has a relatively large geographic range compared to many other species in the genus *Plethodon* (Petranka 1998). In Ohio, the geographic overlap of the ranges of these two species extends throughout most of the state; but, when viewed at a finer scale, the geographic overlap is more accurately described as interdigitation (see Deitloff et al. 2008, figs. 1 and 2). In other words, allopatric locations may be more commonly found than sympatric locations. As suggested in Deitloff et al. (2008), this difference between the coarse- and fine-scale views of the geographic distributions in these two species could lead to differing conclusions about the extent of sympatry. Therefore, I addressed two goals in this study. First, I examined the extent of sympatric locations by conducting landscape-scale surveys (rather than using past distribution maps). Second, I monitored four sympatric sites over three years to determine whether the relative population size of either species changed over time (i.e., whether the condition of sympatry was stable or transient).

During the period when the four sympatric sites were monitored, one of these locations was strongly affected by a flood, another location was weakly affected by the same flood, and two locations were physically undisturbed during the study. This disturbance provided a natural experiment to address the relative impact of flooding on these populations over time. Flooding is a common disturbance of salamander assemblages in both aquatic and terrestrial systems; however, most studies have focused on aquatic and semi-aquatic species. In some instances, individuals that survive flooding can exhibit indications of competitive release (Petranka and Sih 1986); however, other species require a longer time period for recovery (Swanson et al. 1998). The impact of floods on terrestrial salamanders is largely unknown.

Materials and Methods

Species Co-occurrence.—I conducted landscape-scale surveys of species presence during spring 2007 and fall 2007. To conduct these landscape-scale surveys, I searched for locations within the distributional overlap of *P. cinereus* and *P. electromorphus*. I identified locations only within counties where both species have been found (sympatric counties) according to distribution maps of Ohio (Pfingston and Matson 2003). I chose 21 sympatric counties from northeastern Ohio (from all possible sympatric counties) because this area contained a concentration of townships (subdivisions of counties) where both species have been found (Pfingston and Matson 2003). Within each of these 21 sympatric counties, I identified locations that could contain salamanders by using topographic maps to determine which areas contained wooded habitat. After arriving at a location, if the area was indeed suitable habitat, I searched for salamanders. At each of these locations, I recorded the number of individuals of *P. cinereus* and/or *P. electromorphus* at that location. Each location was searched for a minimum of 20 minutes to determine the presence of salamanders. If any salamanders were found, the area was searched exhaustively (i.e., all cover objects were overturned and the boundaries of each site were delineated by rivers, roads, or non-forested private property). I adapted the distribution maps of Pfingson and Matson (2003) using these locations as well as the locations mentioned below (sites A, B, C, and D), which also were located within sympatric counties (map is described in results). Locations where I found no salamanders might have contained salamanders; however, these areas were not included in the analysis described below and therefore

Fig. 3. Site A, where flooding swept most of the cover objects from the slopes of the ravine into the stream.

Fig. 4. Photograph of a location with allopatric *Plethodon cinereus*. This location was 8 mi NW of Newark in McKean Township, Licking County (40°08'06"N, 82°32'05"W).

did not influence results. I am confident that locations described as being allopatric were indeed allopatric because: (1) Each location was searched exhaustively, and (2) when sympatric locations were identified, minimal search effort found both species (search time as low as 5 min and two total salamanders confirmed the presence of both species). Also, when analyses were calculated excluding sites with fewer than five total salamanders, results were the same. Note that I focused only on counties where both species had been documented, and, thus, had the best chance of finding sympatric locations if they existed.

To test the hypothesis that *P. cinereus* and *P. electromorphus* co-occur less frequently than expected by chance, I used the collection data obtained from the landscape-scale surveys to construct a presence/absence matrix. This matrix was used to determine whether co-occurrence between *P. cinereus* and *P. electromorphus* was best described as segregation, aggregation, or random. I used the C-score index (Stone and Roberts 1990) as a measure of co-occurrence. This index is calculated as:

$$C_{ij} = (r_i - S)(r_j - S)$$

where S is the number of shared sites (sites containing both species) and r_i and r_j are the number of occurrences (row totals) for species i and j. If the C-score was greater than expected by chance, species segregate; if the C-score was smaller than expected by chance, species aggregate. I used EcoSim Version 7.0 (Gotelli and Entsminger 2007) to compare the observed C-score to the average C-score generated from 10,000 randomly constructed assemblages. I used a model where row values were retained so each species only occurred as often as in the observed matrix (fixed sum) and where sites (columns) are equally likely to be represented (equiprobable), eliminating observed differences in species richness of sites in the null assemblages.

Flood.—I located four sympatric sites in Ohio during spring 2004. Site A was ~3 mi E of Lisbon in Elk Run Township, Columbiana County (40°46'04"N, 80°43'33"W); Site B was 10 mi N of Lisbon in Salem Township, Columbiana County (40°49'48"N, 80°49'19"W); Site C was 12 mi NE of Newark in Perry Township, Licking County (40°10'01"N, 82°15'28"W); and Site D was 9 mi N of Newark in Washington Township, Licking County (40°11'27"N, 82°26'38"W). These four sites were monitored during seven collecting trips from spring 2004 to fall 2007. Spring collecting trips in 2004, 2005, and 2007 occurred in early May, and fall collecting trips in 2004, 2005, 2006, and 2007 occurred in late September and early October. These four sites were similar in composition in that they all occurred in temperate deciduous forest in east-central Ohio. During late August and September 2004, severe and frequent rains resulted in flooding of Sites A and B. When Site A was visited on 25 September 2004, I observed that most of the rocks (used as cover objects by salamanders) and leaf litter (used for foraging and refugia during dryer conditions) had been swept into a ravine located within the site (Fig. 3). Salamander habitat at Site B was also disturbed by the flood, but not as severely, and many cover objects remained on the slope. Sites C and D were not flooded during the study period.

During visits to each site, I collected adult *P. cinereus* and *P. electromorphus* and recorded the number of individuals of each species. During fall 2004, Sites B and C were searched until approximately 25 salamanders of each species were collected for other research. Therefore, this collecting season was not included in the analyses

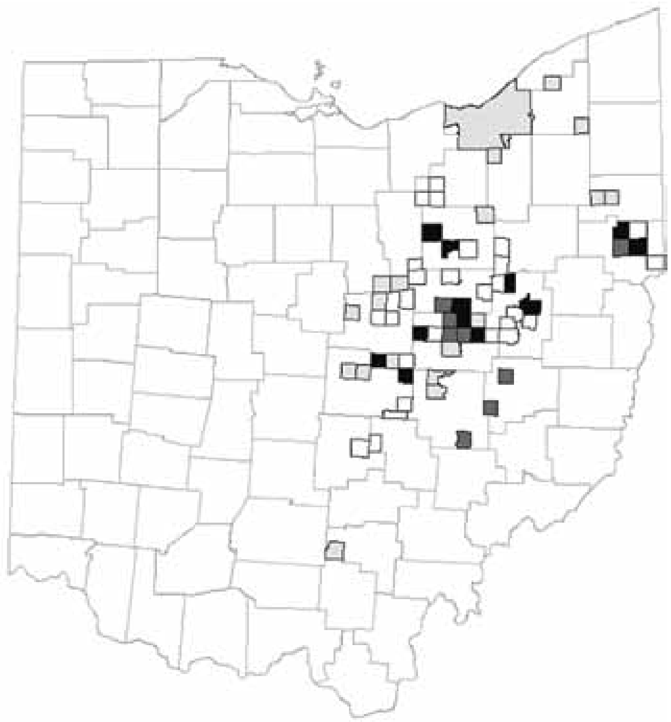

Fig. 5. Results of landscape surveys of *Plethodon cinereus* and *P. electromorphus* in Ohio showing surveyed townships outlined in black (maps adapted from Ohio Department of Transportation 2007). Townships with sympatric locations are filled with black, allopatric *P. cinereus* locations with light gray, and allopatric *P. electromorphus* locations with dark gray. Townships where I found no salamanders are white.

and is reported only because this was the collection that occurred immediately after the flood and Site A contained only one salamander. All collecting was conducted at 0700–1100 h, and all salamanders were captured by hand. All sites during each collection season were searched exhaustively (all cover objects were overturned and the boundaries of each site were delineated by rivers, roads, or non-forested private property). Therefore, the area at each site that was searched was the same for each collection season. Unfortunately, time spent collecting salamanders was not recorded for the first collecting season (spring 2004). Three people collected salamanders during this season and each site was searched for approximately 1–2 h (3–6 collecting h/site). For all other collecting seasons, two people collected salamanders, and collection effort per site was similar (Site A: 3 h each collection season; Site B: 2–4 h; Site C: 2.5–4 h; Site D: 2 h). The goal of this paper was to estimate the relative number of individuals of *P. cinereus* and *P. electromorphus*, so actual population sizes were not estimated. Instead, the number of individuals of each species encountered was used to calculate the proportion of *P. cinereus* at each site for each season, and this measure is referred to as "relative population size." To determine if this proportion changed significantly over time, I compared the proportion found during the second through seventh collecting seasons (post-flood) to the proportion found during the first collecting season (pre-flood) using chi-square tests with $\alpha = 0.05$.

Results

Species Co-occurrence.—I found 20 allopatric locations for *P. cinereus* (Fig. 4), nine allopatric locations for *P. electromorphus* (two locations were within the same township), and 12 sympatric locations; I did not find any salamanders in 27 townships. For the adapted map (Fig. 5), each township was coded as containing allopatric *P. cinereus*, allopatric *P. electromorphus*, both species (sympatric), or neither species. *Plethodon cinereus* and *P. electromorphus* co-occurred less frequently than was expected by chance (C-score = 180; P = 0.0008). Therefore, the distributions of *P. cinereus* and *P. electromorphus* in regard to the presence of the other species would be best described as segregation, as opposed to aggregation or random.

Flood.—Over the course of this study, *P. cinereus* was more common than *P. electromorphus* at all monitored sympatric sites. At both flood sites (A and B), I recorded a temporal pattern in which *P. cinereus* significantly increased in relative population size compared to *P. electromorphus* (Table 1). Furthermore, in fall 2004 (immediately after the flood), I found only one adult *P. cinereus* and no *P. electromorphus* at Site A. At the non-flooded sites (C and D), relative population sizes of *P. cinereus* and *P. electromorphus* did not change significantly (Table 1). More specifically, at Site C, a non-significant increase in *P. cinereus* occurred until fall 2006, when the relative population sizes were similar to the first collecting season. While the change was not significant at Site D, no *P. electromorphus* were found during the final collecting season.

Discussion

The first goal of this study was to examine the extent of sympatry between *P. cinereus* and *P. electromorphus* in Ohio, and I addressed this goal by conducting landscape-scale surveys. I found that allopatric sites of *P. cinereus* are more common than sympatric sites and allopatric sites of *P. electromorphus*, that co-occurrence was less than expected by chance, and that, at sympatric sites, *P. cinereus* is more abundant. The second goal of this study was to monitor sympatric locations to determine if the condition of sympatry was stable over time. I found that at one location, local extinction of *P. electromorphus* might have occurred (Site D); at one location, the relative number of each species remained approximately the same (Site C); and at two locations, the relative population size of *P. cinereus* increased over time (Sites A and B), but the site remained sympatric.

Flooding occurred at the two sites where *P. cinereus* increased, suggesting that flooding could affect relative population sizes of each species. Furthermore, *P. cinereus* returned more quickly after the flood to Site A than *P. electromorphus*. At Site B, where flooding occurred but did not destroy the entire terrestrial habitat, the community changed significantly, but this change occurred over a longer time period. This major disturbance appeared to affect the population of *P. electromorphus* more than the population of *P. cinereus*. Evidence suggests that flooding influences the relative population size of these species through one of three, non-mutually exclusive mechanisms: (1) Enhanced competitive exclusion of *P. electromorphus* by *P. cinereus*, (2) a change of environmental characteristics at the flooded sites, making these sites unsuitable for *P. electromorphus*, or (3) a slower rate of reestablishment for *P. electromorphus* relative to *P. cinereus*.

To my knowledge, this is the first study that examined the effects of flooding on terrestrial salamanders. Natural disturbance events, such as flooding, provide rare opportunities to study population dynamics that cannot be understood with laboratory experiments. Flooding can disrupt populations of terrestrial salamanders in multiple ways, including damaging the physical environment by removing cover objects that are required for their survival, decreasing population sizes of potential competitors and predators, or temporarily removing all individuals.

In this system, local distribution patterns reveal that complex interactions occur between these two species and possibly with the environment or other species (such as predators) not studied. Competition often plays some role in the interactions of species, but the importance of its effects in a community are context-dependent and other factors are important as well (Tello et al. 2008), For example, disturbance history (Hyde and Simons 2001) and predation (Connell 1975) can suppress densities to chronically low levels, so that shared resources never become limiting — which would promote co-occurrence. Unfortunately, the effect of predators on communities of *Plethodon* is understudied and should be examined. A full understanding of

Table 1. Number of individuals (n) of each species collected during sampling periods and the proportion of total individuals that were *P. cinereus* (%Pc). At Site A during fall 2006 and 2007, the proportion of *P. cinereus* to *P. electromorphus* is significantly greater during the first collection season indicating the impact of the flood on relative population sizes. In addition, at Site B where minor flooding occurred, the proportion of *P. cinereus* to *P. electromorphus* is significantly greater during fall 2006 and 2007. P-values (P) from chi-square tests are provided.

	***P. cinereus* (*n*)**	***P. electromorphus* (*n*)**	**%Pc**	**P**
Site A: Flood Site				
Spring 2004	34	8	0.81	—
Fall 2004	1	0	—	—
Fall 2005	32	4	0.89	0.23
Fall 2006	33	1	0.97	0.02*
Spring 2007	15	1	0.94	0.19
Fall 2007	40	3	0.93	0.04*
Site B: Weak flooding				
Spring 2004	23	9	0.72	—
Fall 2004**	25	22	0.53	—
Spring 2005	27	5	0.84	0.12
Fall 2006	58	2	0.97	<0.0001*
Spring 2007	22	5	0.81	0.27
Fall 2007	17	1	0.94	0.03*
Site C: No flooding				
Spring 2004	49	13	0.79	—
Fall 2004**	25	25	0.50	—
Spring 2005	28	3	0.90	0.12
Fall 2006	82	28	0.75	0.25
Site D: No flooding				
Spring 2004	25	3	0.89	—
Fall 2004	8	1	0.89	0.97
Spring 2007	7	0	1.00	0.36

* Indicates significant differences between the percent of *Plethodon cinereus* during first collecting season and subsequent collecting seasons.

** The number of salamanders collected was intentionally approximately 25 for each species. These collecting seasons were omitted from analyses.

the role of competition, predation, and environmental conditions in regulating populations requires broad spatial and temporal studies (Petranka and Sih 1986) and was beyond the scope of this investigation. Future studies should lead to an understanding of the relative influence of competition, predation, and disturbance in the community dynamics of terrestrial salamanders.

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Male *Sphaerodactylus thompsoni* from a locality off the Alcoa Road, north of Cabo Rojo. This individual is on a limestone rock that typifies the preferred substrate of this species in the area.

Notes on Activity Patterns of Five Species of *Sphaerodactylus* (Squamata: Sphaerodactylidae) from the Dominican Republic

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Photographs by the senior author except where noted.

Dwarf geckos of the genus *Sphaerodactylus* ("sphaeros") are one of the dominant components of the West Indian herpetofauna in terms of species richness and sheer local abundance — 88 West Indian species and numerous subspecies are presently recognized (Henderson and Powell 2009) and some populations approach densities of 60,000/ha (Rodda et al. 2001). Indeed, they are such a ubiquitous feature of Caribbean herpetology that sphaeros and rum might well be staples of Caribbean islands. These geckos occupy the full scope of available habitats in the West Indies — coastal regions including mangrove thickets, cactus-covered xeric badlands, and montane cloud forests.

Sphaeros are tiny geckos, and include the smallest amniote species (Hedges and Thomas 2001). Overall, the genus is considered to be diurnally active, although nocturnal activity is reported for a few species. Most species live a secretive, semi-fossorial lifestyle that, coupled with their miniscule size, renders observation challenging (e.g., Henderson and Powell 2009). This difficulty has no doubt contributed to the fact that we currently know next to nothing about their behavior, ecology, distributions, and functional morphology. This dearth of knowledge, however, makes sphaeros very rewarding animals to study. Almost every day of fieldwork spent on these geckos generates new discoveries. In this paper, we discuss


MIGUEL LANDESTOY

Male *Sphaerodactylus ladae* from Parque Nacional Francis Caamaño.

Male *Sphaerodactylus leucaster* from the karst hills of Monte Río, south of Azua. This lizard was active at night.

Juvenile female *Sphaerodactylus ladae* collected at night from Parque Nacional Francis Caamaño.

some recent observations of nocturnal or crepuscular activity patterns in five poorly known species from the Dominican Republic.

Nocturnality is the ancestral lifestyle for geckos, although diurnality has evolved multiple times. In fact, the family Sphaerodactylidae contains a mixture of diurnal and nocturnal species. The genera *Aristelliger*, *Saurodactylus*, *Euleptes*, and *Teratoscincus* are predominately nocturnal (although some species of *Aristelliger* are known to bask on exposed surfaces during the day; Henderson and Powell 2009). Every other genus in the family is largely diurnal, although nocturnal or crepuscular species are known from *Gonatodes*, *Pristurus*, and *Sphaerodactylus*. Sphaeros with recorded nocturnal activity patterns include *S. inaguae*, from xeric coastal areas in the Bahamas, *S. roosevelti*, from xeric forests of southwestern Puerto Rico, *S. savagei* from the xeric southeastern coast of the Dominican Republic, and *S. sputator* from the northern Lesser Antilles (references in Schwartz and Henderson 1991, Henderson and Powell 2009).

Inspection of where these species fall within published phylogenies (Hass 1991, Gamble et al. 2008) suggests that nocturnality has evolved multiple times within *Sphaerodactylus*. However, the differences between diurnal and nocturnal lifestyles may be exaggerated by human perception. Because sphaeros are largely semi-fossorial, they may be "active in a perpetual twilight" (Henderson and Powell 2009) regardless of the time of day. Therefore, even diurnally active sphaeros might possess the ocular morphology more typical of nocturnal lizards. In any case, so little is known about these geckos that a basic understanding of activity patterns is critical for accurate survey work. Indeed, for most species, no published data address activity patterns.

Sphaerodactylus leucaster and *S. thompsoni*

Sphaerodactylus leucaster and *S. thompsoni* are poorly known xerophilic geckos from Hispaniola. During recent research trips to the Dominican Republic, we collected individuals of these species under dead *Agave* plants and rocks, respectively, during the day. Shortly after collecting these animals, we noted the presence of vertically elliptical pupils, which stands in contrast to the round pupil characteristic of most species in the genus, and is more typical of nocturnal geckos. Considering the oppressive heat of the habitat (exposed surface temperatures often surpass 60 °C during the heat of the day), we decided to survey habitats at night to see if these geckos were active, and perhaps more abundant than daytime surveys implied.

On successive nights, we observed multiple animals of both species moving around on exposed surfaces. For *S. leucaster*, we observed a total of 20 individuals (all adults or sub-adults) over the course of two separate nights (21 August 2009, 14 January 2010) on a karst-strewn hillside south of Monte Río, Azua Province. We found individuals of both sexes on the ground or on the sides of rocks revealed by direct encounters or reflective eye-shines. Once disturbed, geckos would run for the nearest cover, which was either dead *Agave* or karst talus. For *S. thompsoni*, we observed >30 animals during multiple nights of searching (August 2009 and January 2010) and at multiple localities along the Alcoa Road between Cabo Rojo and Las Mercedes. The geckos were on karst rocks at 2000–2300 h, and included both sexes and all age classes. Animals were frequently found on vertical rock faces, and were rarely far from crevices. A number of animals also were found by flipping small talus piles. In such instances, geckos were often on the undersides of the rocks. We found more animals in these piles at night than we did with similar effort during the day. Our field observations are recapitulated for both species by captive specimens; animals emerge after the lights are turned off and remain active for several hours.

We collected microhabitat temperature data for some individuals of *S. thompsoni* by using an infrared temperature gun to record the surface temperature at the site of encounter. The average surface temperature was 31.9 ± 1.5 °C ($N = 6$). We also recorded the temperature of active, but undisturbed, tarantulas (*Phormictopus cancerides*), which we have witnessed killing *Sphaerodactylus ladae*. The average tarantula temperature was 29.1 ± 0.8 °C ($N = 3$). Although the sample size is small, a Student's *t* test indicated that the difference in average temperatures of these species was significant ($t = 2.97$, $df = 7$, $P = 0.02$). These limited and admittedly very preliminary data suggest that interactions between tarantulas and geckos might be minimized by different thermal preferences.

Female *Sphaerodactylus cryphius* from an old rock quarry between Duvergé and Jimaní. The scale is in mm. This gecko was collected as an adult underneath a dead *Agave* during the afternoon in August 2008; she is still alive as of 27 January 2011.

Sphaerodactylus ladae

Sphaerodactylus ladae is known only from the Dominican Republic, where it inhabits the scrubby foothills of the Sierra de Martín García and the surrounding lowlands toward the city of Azua. We have collected this species from near Ranchería and at Parque Nacional Francis Caamaño. To our knowledge, the latter site represents the most northern and eastern records for this species. Geckos were abundant at both sites. At Ranchería, we collected animals during the day from beneath dead and rotting *Agave* plants, completely oblivious to what we would discover later at Parque Nacional Francis Caamaño. In January 2010, one of us (ML) visited the park to photograph the area at sunset and conduct a preliminary survey of the area at night. This trip resulted in the collection of three adult *S. ladae*, which were moving around, fully exposed, just after sunset. We revisited the site one year later in January 2011 at 2200–2300 h and found five animals actively moving around in shallow leaf litter collected on a boulder-strewn hillside. All were female and included two adults and three juveniles (DPS sexed them based on pattern and the absence of an enlarged escutcheon patch). We observed but failed to secure an additional three animals. The habitat at this site consists of karst limestone boulders with a short scrub canopy. The exposed ground between large rocks consists of shallow leaf litter atop gravel. We observed all of the geckos completely exposed on these patches of leaf litter.

We also collected three *S. leucaster* at Parque Nacional Francis Caamaño, where they occur sympatrically with *S. ladae*. One adult female and two juveniles were active at 2200–2300 h in exposed patches of leaf litter adjacent to large limestone rocks. Sympatry between *S. ladae* and *S. leucaster* is noteworthy because these species are similar in size, activity pattern, and appearance (males have a pale gray body with a streaked, bright yellow head; females are a dull purple-gray, with bold dorsolateral lines).

Sphaerodactylus cryphius

A final xerophilic species we have observed while active at night is *S. cryphius*. This observation, however, is limited to a single individual observed after 2200 h crawling in leaf litter near the base of a limestone cliff at an old rock quarry between Duvergé and Jimaní. Additional work is necessary to clarify if this is an isolated incident or typical of this species.

Sphaerodactylus cochranae

Sphaerodactylus cochranae is known only from the southern shore of the Bahía de Samaná. This beautiful and rarely seen species has been collected by only a small handful of herpetologists. On 11 September 2009 at 1800–1845 h (just around dusk), we observed four geckos within a 50-m radius on leaf litter near the coast in Parque Nacional Los Haitises. Three of the sightings were between 1830 and 1845 h, suggesting that they were just becoming active. Alternatively, the animals were ending activity and seeking roosting spots; however, this seems unlikely, considering that we spent much of the day in suitable habitat and did not collect any individuals. Additionally, previous informal nighttime surveys in Los Haitises conducted in 1996–1998 by one of us (REG) recovered active *S. cochranae* in and around bromeliads.

Discussion

Our success in finding and collecting *S. ladae, S. leucaster,* and *S. thompsoni* increased at night. Furthermore, we substantially reduced our impact on the habitat during nocturnal searches because we did not have to disturb dead *Agaves* and rock piles. Considering the close phylogenetic relationship of *S. leucaster* and *S. thompsoni*, we hypothesize that the related species *S. asterulus, S. rhabdotus*, and *S. shrevei*, which also inhabit xeric habitats, are

RICHARD E. GLOR

Female *Sphaerodactylus cochranae* perched on the top leaf of a bromeliad that is common at localities where this species lives. These geckos have been seen crawling in the axils of this plant at night.

also nocturnal and might occur in greater abundance than daytime surveys imply. Similarly, *S. schuberti*, the presumed relative of *S. ladae* from the Sierra de Neiba (Thomas and Hedges 1998), might be nocturnal as well. *Sphaerodactylus schuberti* is only known from the type locality, but this area is very similar to habitats in which we have collected *S. ladae*. Similarly, the ranges of these species might well have been underestimated.

Imagining a gecko as small as *S. cryphius* surviving in brutally hot and dry habitats is difficult. Nocturnal behavior could conceivably allow this species to forage when surface temperatures have cooled substantially from daytime highs. However, we must note that we never observed *S. plummeri* active at night during surveys for *S. thompsoni*. *Sphaerodactylus plummeri* is approximately the same size as *S. cryphius* and lives in similar habitats on the southern part of the Barahona Peninsula. However, we readily collected *S. plummeri* during the day at the same sites at which we collected *S. thompsoni* the night before. Although more research is necessary, this is highly suggestive of temporal niche partitioning.

A fisheye view of typical habitat of *Sphaerodactylus thompsoni* and *S. plummeri*. Note the high percentage of exposed surfaces and xerophytic vegetation.

A fisheye view of the habitat where we collected *Sphaerodactylus cryphius* and *S. rhabdotus* during the day. This habitat, with a mixture of scrub vegetation, dead *Agave*, and limestone rocks is typical of localities where we have collected *S. ladae* and *S. leucaster*.

Coastal leaf litter in Parque Nacional Los Haitises where we collected *Sphaerodactylus cochranae*. The orange flag in the center of the image denotes the exact place where a gecko was first seen.

Juvenile *Sphaerodactylus schuberti* collected at the type locality near La Descubierta in August 2009.

Male *Sphaerodactylus plummeri* collected at the type locality along the Alcoa Road in August 2009.

Nocturnality has evolved multiple times within *Sphaerodactylus*, and nocturnal sphaeros are largely restricted to hot and dry habitats. Although a more rigorous comparative analysis is necessary (and forthcoming), we hypothesize that nocturnality is an adaptation to xeric conditions as it would almost certainly reduce evaporative water loss by restricting activity to cooler periods. Such transitions between activity patterns may be facilitated if sphaeros are already pre-adapted to low-light conditions because of their semi-fossorial nature. Future work should investigate the ocular morphology of species in a comparative framework, as well as quantify activity across species in terms of ambient light conditions — instead of emphasizing time of day. The observation that *S. leucaster* and *S. thompsoni* possess vertically elliptical pupils, typical of most nocturnal geckos, whereas *S. ladae* has round pupils, suggests that multiple paths could facilitate seeing in the night.

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Urban box turtles, such as this Ornate Box Turtle (*Terrapene ornata ornata*) in Lubbock, frequently cross roads and sometimes get hit by cars.

Herpetofauna Admitted to the South Plains Wildlife Rehabilitation Center (Lubbock, Texas): A Two-decade Perspective

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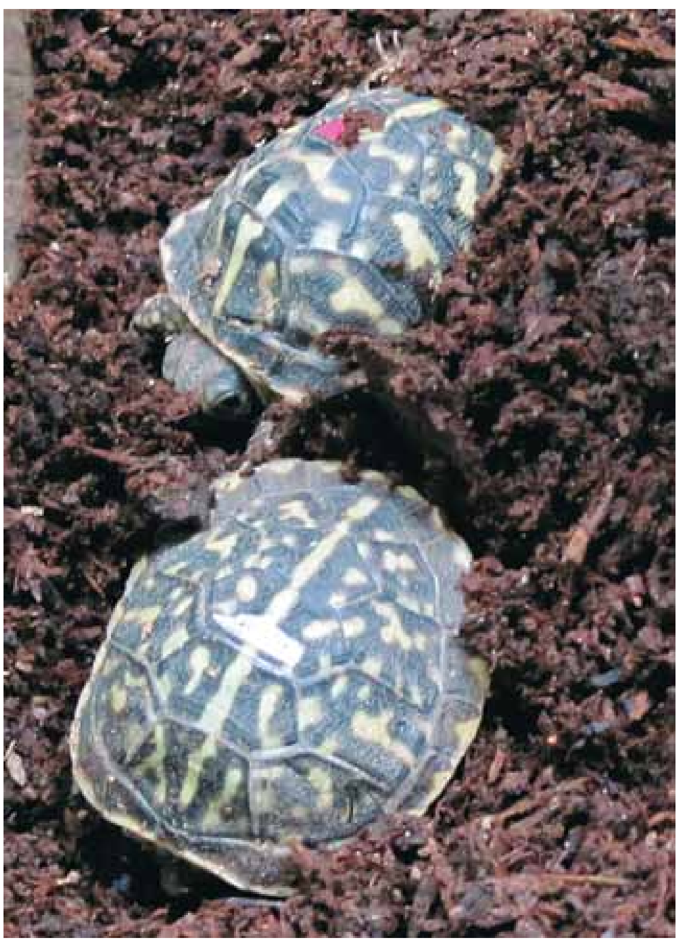
All photographs by Gad Perry except where indicated.

More humans than ever live in urban areas, creating complex environmental challenges including interactions with native species and the introduction of species not native to the region or even continent (Vitousek et al. 1997, Olden et al. 2006, Mitchell et al. 2008, Adams and Lindsey 2009). Wildlife rehabilitation centers offer a venue for animals that have suffered from the inevitable encounters that occur between humans and animals, whether wild (e.g., animals injured by cars or pets) or captive (e.g., escaped pets; Karesh 1995). The exact number of certified wildlife rehabilitators in the United States is unknown (National Wildlife Rehabilitators Association 2008), but estimated at 500–1,000 (Southeastern Outdoors 2009, The Wildlife Rehabilitation Information Directory 2008).



These hatchling Ornate Box Turtles hatched at the rehabilitation center in late 2010. They will likely be released next spring in an appropriate habitat in town — this species is common and popular inside the Lubbock city limits.

A Red-eared Slider (*Trachemys scripta elegans*) and baby Ornate Box Turtles (*Terrapene ornata ornata*; at left) are kept inside during the winter at the South Plains Wildlife Rehabilitation Center. During the spring and summer, this area normally houses many more turtles.

The South Plains Wildlife Rehabilitation Center (SPWRC), located in Lubbock, Texas and serving a large area in the southern plains, rehabilitates and releases injured, sick, displaced, or orphaned wildlife (South Plains Wildlife Rehabilitation Center 1988). Each year, SPWRC accepts a variety of animals, many of which are non-native to the region. The admissions records kept by the center provide a unique record of the interactions of residents with reptiles and amphibians, a valuable record of the propagule pressure contributing to the growing invasive herpetofauna (e.g., Kraus 2009, Powell et al. 2011), and how these change over time. Here we report the numbers of native and non-native amphibians and reptiles admitted to the SPWRC over two decades and analyze both taxonomic and temporal patterns. Our aim is to assess the magnitude of human-herpetofaunal interactions in this mid-sized city, which will hopefully offer an example of what many other urban centers across the nation experience. These data can be used to better manage such interactions at a community level and assist in preparing a realistic response plan to non-native species arrivals.

Methods

We examined all SPWRC admission records for the years 1991–2009. For each we recorded species identified by SPWRC staff (until recently, identifications were provided by non-herpetologists and could not be independently verified by us), arrival date, reason the animal was brought in, where it was found, injuries sustained (if any), and ultimate disposition (died, had to be euthanized, or was released). We categorized each record as belonging to a species native or non-native to the region. Records varied in detail, and not all data were available for each individual animal.

Results

Almost 700 individuals belonging to at least 43 identified species were admitted to the SPWRC between 1991 and 2009. The majority of these, 626 individuals (616 reptiles and 10 amphibians belonging to at least 19 species) were native, and another 52 (48 reptiles and 4 amphibians) belonging to at least 24 species were non-native (Fig. 1). By far, most admitted individuals were native chelonians, primarily Ornate Box Turtles (*Terrapene ornata ornata*; N = 342) and Red-eared Sliders (*Trachemys scripta elegans*, N = 138). Although the latter species is native to the broad region, all or some of these might have originated in the pet trade. Other native turtles included Common Snapping Turtles (*Chelydra serpentina*, N = 20) and Yellow Mud Turtles (*Kinosternon flavescens flavescens*, N = 15). The most common lizard was the Texas Horned Lizard (*Phrynosoma cornutum*, N = 36), with 1–2 individuals each of Eastern Collared Lizard (*Crotaphytus collaris*), Lesser Earless Lizard (*Holbrookia maculata maculata*), and an unidentified skink (which may or may not be native; and therefore was not included with the non-natives). The most common snakes were Bullsnakes (*Pituophis catenifer sayi*, N = 15) and Checkered Garter Snakes (*Thamnophis marcianus*, N = 13), with 1–2 individuals each of a kingsnake species (*Lampropeltis* sp.) (which, like the skink, may or may not be native), Great Plains Rat Snake (*Elaphe emoryi*), Western Diamondback (*Crotalus atrox*), Western Hognose (*Heterodon nasicus*), and Western Rattlesnake (*Crotalus viridis*). Among native amphibians the most common was the Barred Tiger Salamander (*Ambystoma tigrinum mavortium*, N = 5), with smaller numbers of unidentified spadefoots, toads, and "frogs" (which also may or may not be native) completing the list.

Turtles also dominated among non-natives, with Common Musk Turtles (*Sternotherus odoratus*, N = 9), Desert Box Turtles (*Terrapene ornata luteola*, N = 6), and African Spurred Tortoises (*Centrochelys* [formerly *Geochelone*] *sulcata*, N = 3) being the most common, followed by one or two each of the Desert Tortoise (*Gopherus agassizii*), Texas Tortoise (*Gopherus berlandieri*), Red-footed Tortoise (*Chelonoidis carbonaria*), Alligator Snapping Turtle (*Macroclemys temminckii*), Horsfield's Tortoise (*Testudo horsfieldii*), Eastern Box Turtle (*Terrapene carolina*), Sabine Map Turtle (*Graptemys ouachitensis sabinensis*), and Western Spiny Softshell (*Apalone spinifera hartwegi*). Identified non-native arrivals also included 1–3 individuals each of unknown geckos (presumed non-native because no species is native to the region), Green Iguana (*Iguana iguana*), Monitor Lizard (*Varanus* sp.), Striped Plateau Lizard (*Sceloporus virgatus*), Boa Constrictor (*Boa constrictor*), Eastern Corn Snake (*Pantherophis guttatus*), Texas Indigo Snake (*Drymarchon corais erebennus*), Plains Garter Snake (*Thamnophis radix*), Bullfrog (*Lithobates catesbeianus*), American Toad (*Anaxyrus americanus*), and Western Spadefoot (*Spea hammondii*). Perhaps most surprising was the number of crocodilians, most of which were American Alligators (*Alligator mississippiensis*, N = 5). Herpetological admissions gradually increased during the 1990s and remained roughly stable during the decade that followed (Fig. 2). The proportion of non-natives ranged from 0–30% of total admissions for a given year, averaging 7.6%. Turtles dominated admissions during the entire study period (Fig. 3). Their proportion of all herpetological admissions ranged from 70–100% (including three years in which all recorded admissions were turtles), averaging about 85%.

Of the known reasons for admittance of natives, 216 individuals were reported "injured" (the most common injury being "hit by a car"; others included cracked shell, impaled with a fishing hook, attacked by a dog or cat, and disease); 57 were found in or near the road, yard, home, or park; 18 were surrendered pets; and one was brought in for injuring a human. Among non-natives, known reasons for admittance were generally similar: 11 were found in the yard, road, or home; seven were injured; and three were confiscated by authorities (Texas Parks and Wildlife or Animal Control).

Of the known dispositions for natives, 361 individuals were released (location usually unspecified), 54 were euthanized, 23 died, three were returned to the finder, and two were transferred to a local pet shop. Unfortunately, dispositions of non-natives followed a similar pattern, with 21 being "released," seven transferred to a local science museum or a zoo, three dead, and two euthanized.

Discussion

Native reptiles and amphibians made up the majority of all herpetofauna entering SPWRC in 1991–2009. Overall numbers increased during the 1990s, presumably a result of the greater exposure the Center has achieved

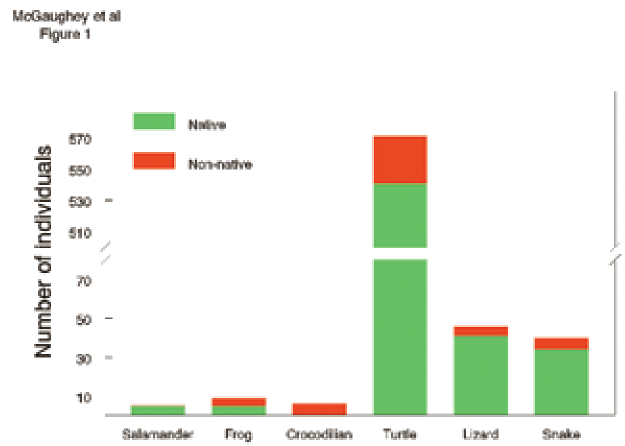


Fig. 1. Numbers of amphibians and reptiles admitted by the South Plains Wildlife Rehabilitation Center over the entire period 1991–2009.

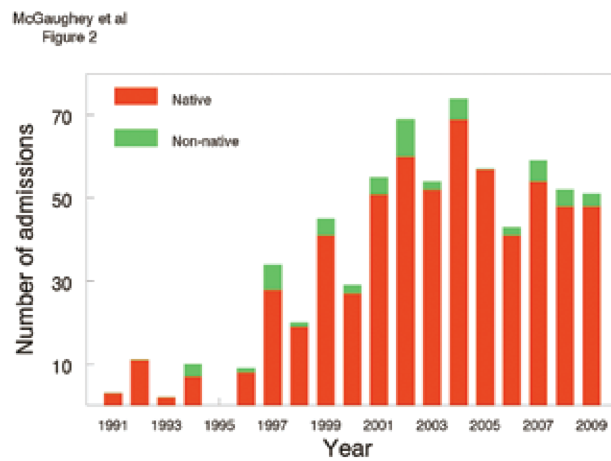


Fig. 2. Numbers of natives and non-natives admitted by the South Plains Wildlife Rehabilitation Center in 1991–2009.

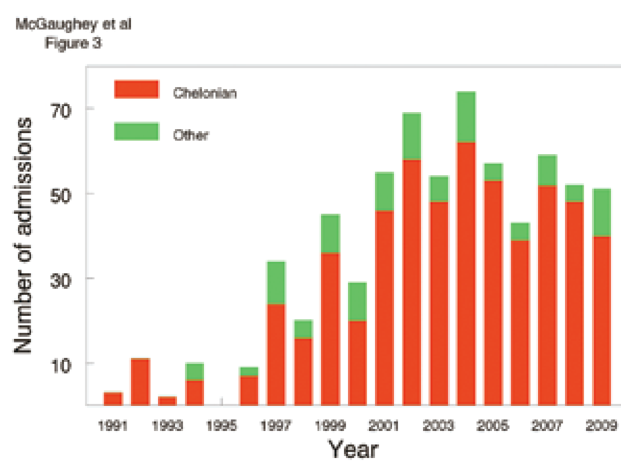
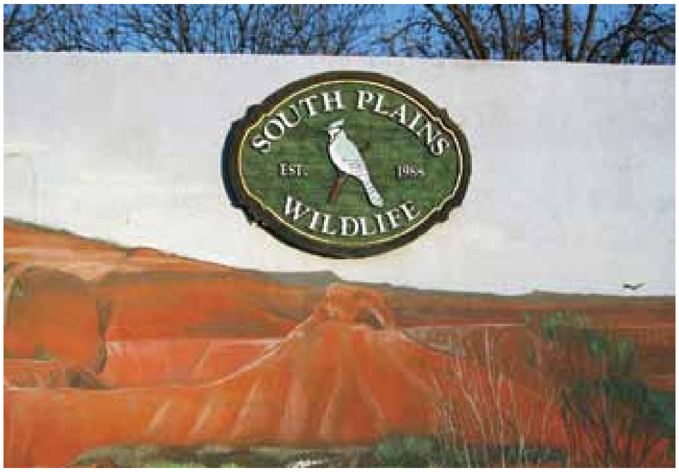
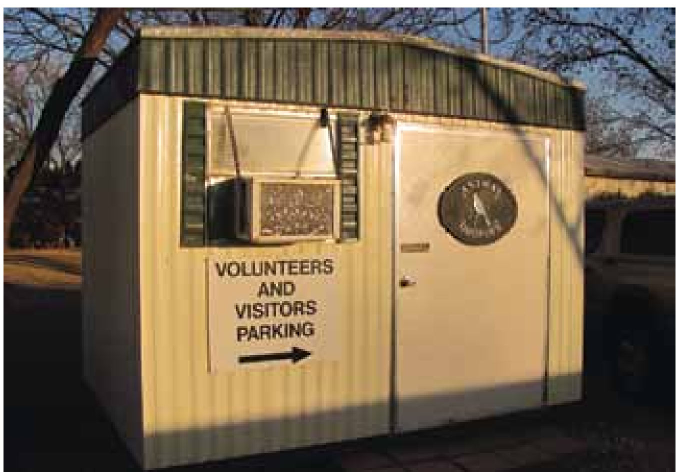


Fig. 3. Relative importance of chelonians in herpetological admissions by the South Plains Wildlife Rehabilitation Center in 1991–2009.

during this period, following its establishment in 1988. Most animals were brought in because of an injury and ~20% either died or had to be euthanized. This left the SPWRC with a substantial number of now-healthy animals in need of disposition; most of these were released in town or nearby.



A mural of regional scenery, some native vegetation, and the center's logo welcome visitors at the roadside entrance.



Citizens drop off animals in this building at the entrance to the center. They are asked to provide information about collection circumstances and encouraged to leave a donation to help defray the costs of treating animals.

During the summer, this pond serves as home for several rehabilitated turtles, mostly Red-eared Sliders.

Percy the Pelican is one of many rehabilitated animals at the center.

A child examines a statue of a raptor in the area reserved for presentations for the general public. Education is a big part of the mission of the center.

This tortoise, initially identified as a Sulcata Tortoise (*Centrochelys sulcata*), native to Africa, was found roaming alongside a Texas highway. It is one of several such animals to reach the center in recent years.

Non-native species, most of them likely former pets, average ~8% of annual admissions. This number may be a gross under-estimate, because many of the Red-Eared Sliders received by the center may have originated in the pet trade and likely represent non-local genetics. Even ignoring this, the data include several alarming features. First, the number of non-native species being admitted is slightly larger than that of natives. Second, large and potentially aggressive species such as crocodilians are common. Third, at least some of them, such as the monitor lizard (a Savannah Monitor, *Varanus exanthematicus*, captured in a back yard; G. Perry, unpubl. data), the Red-Eared Sliders, and the Bullfrogs, are capable or may be capable of surviving in the Lubbock region. Fourth, our data represent a far-from-complete listing of such animals found in the city. For example, a large albino Burmese Python (*Python bivittatus*) had been captured by city personnel and not delivered to the SPWRC (G. Perry, unpubl. data). Finally, the disposition of many of these animals is far from satisfactory. The python mentioned above was "released" into a city park (G. Perry, unpubl. data), and nearly all surviving non-natives were similarly "released" by SPWRC staff. Our data thus show both introduction pathways identified by Kraus (2009), unintentional (escapes of pets) and intentional (poorly-considered "releases"). For Lubbock, they also support the contention of Kraus (2009) and others that the pet-trade is currently the primary source of animals establishing invasive populations. For example, many of the non-native turtle and tortoise species admitted to SPWRC are those described by Ceballos and Fitzgerald (2004) as being traded in Texas for pets and/or food.

Ornate Box Turtles comprised about half of the chelonians admitted to the SPWRC. The species is common in Lubbock and often encountered by residents, who tend to view it favorably (Sosa 2009, Sosa et al. 2010). Unfortunately, the outcomes for "released" box turtles are rarely happy (Cook 2004, Sosa 2009), a pattern that is common in translocated amphibians and reptiles (Dodd and Siegel 1991, Siegel and Dodd 2002, Germano and Bishop 2008).

Other chelonians were also very common among admitted herpetofauna, perhaps because to the public, turtles are the most charismatic and non-threatening of all reptiles and amphibians. Considering the fear that they often invoke (Morris and Morris 1965), we were pleasantly surprised that quite a few snakes and lizards were also admitted.

Our study suggests that rehabilitation centers at other locations might also be receiving substantial numbers of amphibians and reptiles, an issue we hope that future research will address. It also identifies two areas of concern. First, over the years, SPWRC staff members have not been properly educated about non-native species issues and the consequences of "releasing" such animals. This is unlikely to be limited to admissions of amphibians and reptiles. Thus, well-meaning people helping address urban human-wildlife interactions might be contributing to future problems with invasive species. Clearly, opportunities for improved education exist at this, and likely many other rehabilitation centers. Second, more solutions are needed for disposition of rehabilitated native and non-native wildlife alike: The latter certainly should not be "released" and the record for outcomes in the former is poorly documented and generally discouraging. For example, Rodríguez et al. (2010) reported on the reasons raptors were brought in to a rehabilitation center and stated that over 1,000 were "released into the wild," but not what happened to them post-release. In one of the few studies that looked at post-"release" survival, Bennett (1992) reported that >90% of Gibbons (*Hylobates muelleri*) quickly died. Survival of translocated carnivores can also be poor (Linnell et al. 1997). Success rates for translocated amphibians and reptiles are also discouraging, even where the process is much more carefully conceived than the typical "release" from a rehabilitation center (Dodd and Siegel 1991, Siegel and Dodd 2002, Germano and Bishop 2008). Both the logic and the ethics of investing considerable resources in nursing a sick or injured animal back to health, only to have it die upon leaving the center, are suspect.

Acknowledgements

We thank the South Plains Wildlife Rehabilitation Center for allowing us access to their wildlife admittance records and providing technical assistance. This is MS No. T-9-1206 of the College of Agricultural Sciences and Natural Resources, Texas Tech University.

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JANET WALKER

This Horsfield's Tortoise (*Testudo horsfieldii*), an Asian species common in the pet trade, reached the center after it was found roaming. It is now kept in an outdoor enclosure by one of the authors and is doing just fine, suggesting that it could have survived in Lubbock.

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Some turtles are killed immediately when they meet vehicles, but others are less severely wounded and are brought to the center for rehabilitation.

This Eastern Corn Snake (*Pantherophis guttatus*), clearly a well-fed captive-bred individual, was found on the front porch of a Lubbock resident and brought to the center. It is extremely tame and obviously a pet that was released or allowed to escape.

Texas Horned Lizards (*Phrynosoma cornutum*) such as this one tend to disappear from urban centers but can persist on the outskirts of town and may be transported by residents returning from trips. They regularly show up at the center.

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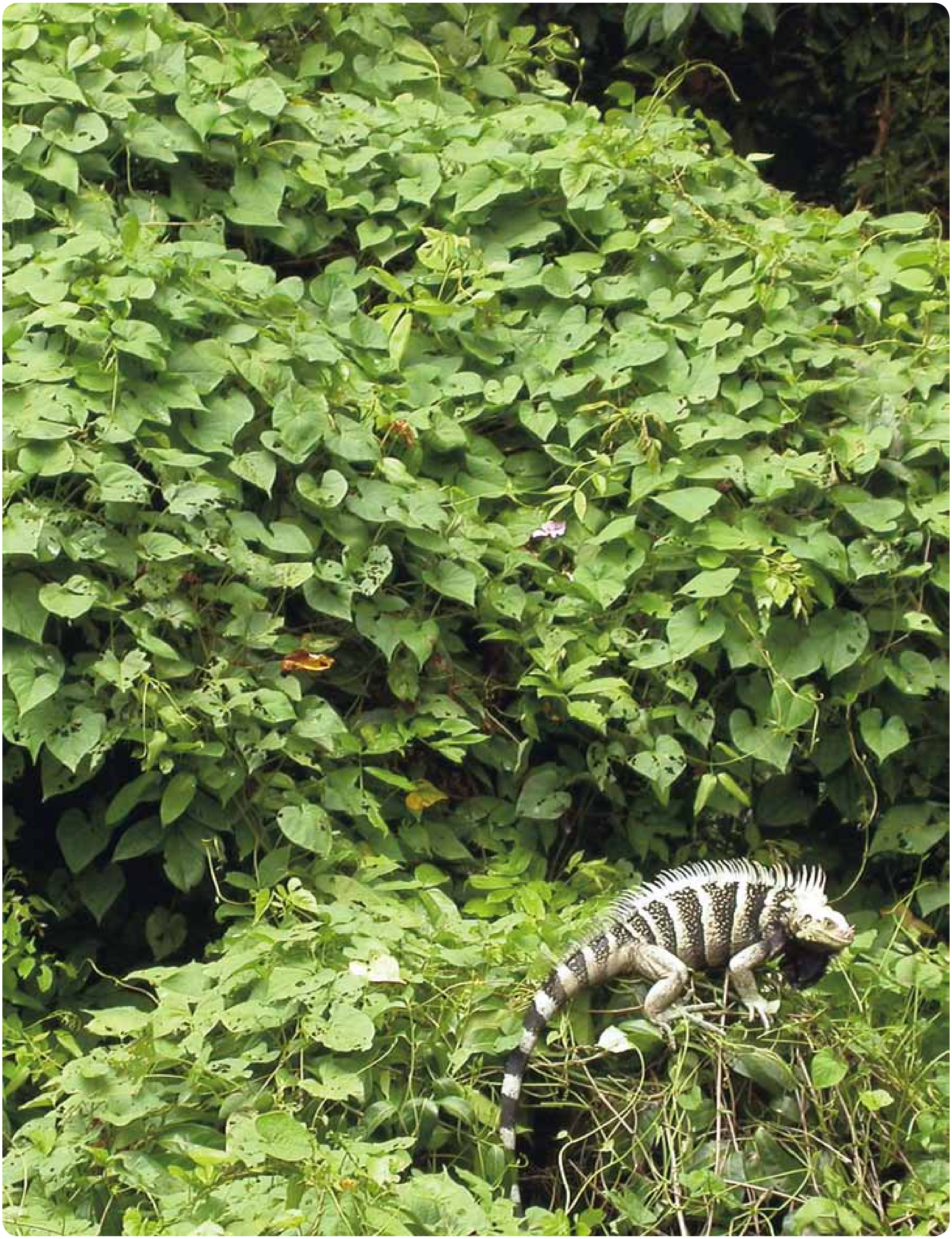

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Saint Lucia Iguana (*Iguana* cf. *iguana*) on "Lyenn Dous" (Umbrella Vine, *Ipomoea tiliacea*).

Native and Alien Iguanas on Saint Lucia, West Indies

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Status of Native Saint Lucian Iguanas

The taxonomy of the Green Iguana (*Iguana iguana*) remains unresolved. Malone and Davis (2004) conducted genetic analyses that "imply that at least three cryptic species may exist [within the taxon currently recognized as *I. iguana*] under the evolutionary and phylogenetic species concepts (Central American, South American, [and] South American [Caribbean] + Lesser Antillean)." They also indicated that their data supported at least two radiations into the Lesser Antilles, "first onto Saint Lucia and more recently onto Saba and Montserrat." Lazell (1973) dismissed the contention that *I. iguana* is a recent introduction (e.g., by Carib peoples; Underwood 1962) to the Eastern Caribbean, although *I. iguana* on Martinique (not considered by Lazell) was introduced in the 1960s (Breuil 2009). Breuil (2002) also rejected Lazell's argument that *I. iguana* is native to Guadeloupe, where it occurs with the endemic Lesser Antillean Iguana (*I. delicatissima*). Powell (2004) and Powell and Henderson (2005) highlighted the importance of insular populations classified currently as *I. iguana* and the risks of assuming they comprise a single species.

The native population of *I. iguana* on Saint Lucia is restricted to the island's northeastern coast, and possibly has been restricted to the eastern coast since the 19th Century (Tyler 1850)[1]. As long as this population is small and has a restricted range, it remains a conservation priority for the Forestry Department of the Ministry of Agriculture, Lands, Forestry & Fisheries (MALFF), the statutory body responsible for terrestrial biodiversity conservation on Saint Lucia. During a biophysical inventory of Saint Lucia's forest resources in 2009, the decision was made to formally refer to the population on Saint Lucia as *Iguana* cf. *iguana* — i.e., similar to, but not confirmed as, *Iguana iguana* (Daltry 2009a, Morton 2009) — and to refer to this population as "the Saint Lucia Iguana," without implying any resolution of the prevailing taxonomic uncertainty.

Concerns about the survival of the Saint Lucia Iguana were expressed by the Saint Lucia Forestry Department (SLFD) and J. Gilardi in the 1990s (Anonymous 1998, Bendon 2003), initiating work in the 2000s by the Durrell Wildlife Conservation Trust (Durrell) and SLFD to evaluate the status of the population and the threats facing it (Morton 2007). More recently, SLFD and Rare Animal Relief Effort (RARE) built upon earlier awareness-raising efforts (Bendon 2003) by means of a "pride" campaign (Narcisse 2009, RARE 2010). This campaign promoted the Saint Lucia Iguana as a flagship species for the island's endangered deciduous seasonal forest habitat, and in particular the deciduous seasonal forests of Saint Lucia's northeastern corridor. Both the pride campaign's iguana mascot and the northeastern corridor were given the name Iyanola, a phonetic version of Iouanalao, the Amerindian name for Saint Lucia, meaning "the land of the iguana" (Jesse 1960). In this respect, the importance of the Saint Lucia Iguana to conservation efforts on the island would remain unchanged regardless of its future taxonomic status. It is Saint Lucia's

[1] Lazell's (1973) report of iguanas on Maria Major island off the southern tip of Saint Lucia is in error (J. Lazell, in litt., 23.VI.2010).

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Saint Lucia Iguana (left) and an iguana from Montserrat (right). Note the differences in scalation between these two West Indian iguana populations.

SAINT LUCIA FORESTRY DEPARTMENT

Iyanola, Saint Lucia's Pride Campaign mascot for the Saint Lucia Iguana and the name bestowed on the island's northeastern corridor, its last known refuge.

largest native terrestrial animal, striking in its appearance, and a cultural signifier of long standing. As such, it is a valuable flagship species that represents a globally threatened habitat type in the insular Caribbean (WWF and McGinley 2007), an area that appears to be the last remaining stronghold of a number of species and subspecies endemic to Saint Lucia, particularly birds and reptiles (Daltry 2009a, 2009b; Morton 2009; Toussaint et al. 2009).

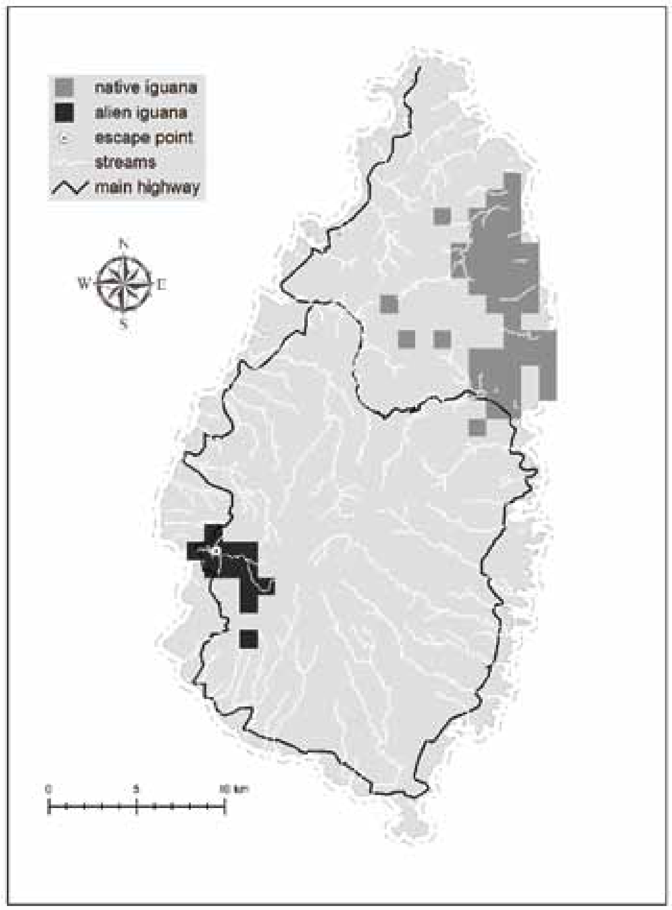
If Saint Lucia were to produce its own Red List, the Saint Lucia Iguana would require a Red List assessment of Critically Endangered (IUCN 2001) at a national level. If this population were to be accorded specific or subspecific taxonomic status, however, it would qualify for a *global* status of Critically Endangered. In either case, this assessment is based on IUCN's (2001) criteria B1a, b (i, ii, iii): Extent of occurrence estimated to be less than 100 km^2 (both the extent of occurrence and area of occupancy are <50 km^2); data indicating that the population is severely fragmented or known to exist at only a single location (one location — northeastern Saint Lucia); and indicators showing continuing decline, observed, inferred, or projected, in the (i) extent of occurrence, (ii) area of occupancy, and (iii) area, extent, and/or quality of habitat (effects of tourism developments, sand-mining, livestock grazing, and other documented threats that are known to reduce the quality and extent of suitable habitats). Historical population baselines are not available for the Saint Lucia Iguana, but this assessment infers a decline in the population based on its very restricted range and the identification of a number of ongoing pressures and threats, most notably that of introduced mammalian predators and the threat of proposed, large-scale tourist development on Saint Lucia's northeastern coast (Morton 2007).

The current range of the Saint Lucia Iguana corresponds to one of the two areas on the island farthest from paved roads (i.e., least accessible to humans, their commensals, and domesticated animals). The other area is a mountainous region of Saint Lucia's highest peaks, from which no iguanas are known (perhaps due to a lack of suitable nesting habitat). This distribution implies that hunting (which still occurs on a small scale, primarily for food; Bendon 2003, Morton 2007) might have been one important historical driver of the inferred decline in the Saint Lucia population. It also underlines one of the threats arising from proposed development on the northeastern coast, over and above conversion of habitat: The improvement of road access and hence human access that, if not regulated in some form, can be expected to increase hunting pressure as well as the density of non-native mammalian predators such as mongooses, dogs, cats, and rats. Improved road access and a higher human population in the northeast might also increase the likelihood that alien iguanas, now establishing on Saint Lucia, are transported into this area, either deliberately as pets or food or inadvertently stowed away in goods.

Introduction and Establishment of Alien Iguanas – Potential Impacts

The question of the taxonomic status of the Saint Lucia Iguana has again come to the fore with the confirmation in 2008 that non-Saint Lucian Green Iguanas are breeding in the dry and mesic forests around Soufrière in the southwest of the island (Morton 2008, Global Invasive Species Database 2010a). The most pressing concern for biodiversity conservation on Saint Lucia is the likelihood of hybridization between native and alien iguanas, potentially compromising the unique genetic identity and locally adapted gene complexes of the Saint Lucia population. *Iguana iguana* is known to hybridize with its congener, *I. delicatissima*, on Eastern Caribbean islands to which it has been introduced (e.g., Day and Thorpe 1996, Breuil et al. 2007).

Competition between native and alien populations is another concern (Henderson and Powell 2009). IUCN's Global Invasive Species Database (2010b) moots the possibility that competition between introduced Green Iguanas and their congener, *I. delicatissima*, might threaten those native



The distribution of the Saint Lucia Iguana and a population of introduced alien Green Iguanas on Saint Lucia, shown as presence in 1 x 1-km squares. The distribution of the Saint Lucia Iguana was determined during five months of islandwide face-to-face questionnaires in 2004–05 (Morton 2007). "False absences" were minimized by questioning large numbers of respondents about iguana sightings in squares where the presence of iguanas had been independently determined prior to the survey. From this, we determined the minimum number of respondents that had to be questioned per square in order to yield 95% confidence that at least one respondent would report a sighting if, in fact, iguanas were present. Sightings determined as "false presences" for the Saint Lucia Iguana (for questionnaire returns, for example, describing captive iguanas or clearly referring to other species, notably *Cnemidophorus vanzoi*) were excluded, although some of the outlying 1 x 1-km squares in the distribution shown here could be false positives, where the presence of iguanas has not been confirmed by searches. The distribution of alien iguanas was determined from questionnaire responses collected in 2008–09. This latter questionnaire is an ongoing effort to maintain an updated demarcation of the spread of the alien population.

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Saint Lucia Iguanas (A, adult male and B, adult female) and alien iguanas introduced in Saint Lucia (C, adult male and D, adult female). The more numerous and prominent nuchal tubercle of the alien iguana, and its larger subtympanic scale, are clearly visible, as is the difference in the color of the iris.

populations. Mean clutch size for the alien iguana is 40 (N = 4 clutches), but with a maximum (to date) of 60, which might more closely represent the true mean as sample size increases. By contrast, mean clutch size for Saint Lucia Iguanas (N = 14) is 23, suggesting that the aliens could out-reproduce the native iguanas. Competition could also be asymmetrical in favor of the aliens if, as the limited data imply, the aliens attain a greater body mass, although this might reflect lower mortality from predators in a population that is putatively still rare compared with that of the Saint Lucia population.

Burton (2004) cited another concern over the introduction of *I. iguana* onto Grand Cayman, the native range of *C. lewisi*, namely confusion of public awareness messages for the conservation of *C. lewisi*. This is a substantive concern given the growing discontent over negative impacts of introduced Green Iguanas on Grand Cayman. As Krysko et al. (2007) noted, the introduction of *I. iguana* to Florida in the 1960s raised little concern, but by the 1990s, the population had exploded and public discontent with iguanas grew.

Other negative impacts of alien iguanas, such as crop damage (particularly to ornamentals), the risk of *Salmonella* infections, or possible predation on bird eggs are almost certainly exaggerated, although invasive iguanas can be a nuisance and are likely to have at least some economic impact on vegetation. What is clear is a high level of public discontent in places where invasive Green Iguanas have become established, in large part due to delayed and inadequate intervention during the early stages of invasion. In Puerto Rico, alien iguanas are considered an air-strike risk on runways at the Luis Muñoz Marín International Airport, causing the suspension of flights six times in one two-month study (Engeman et al. 2005). Sementelli et al. (2008) documented damage to public infrastructure caused by burrowing iguanas introduced into Florida.

At this time, the alien iguana population on Saint Lucia appears to be geographically isolated from the native population, but by dint of small population size rather than any impenetrable geographic barriers. Even if the mountainous rain-forested interior of Saint Lucia does provide a barrier (we have found no reports of Saint Lucia Iguanas in this region), the alien population could still disperse around the coast and come into contact with the native population. Successful nesting outside of captivity has been recorded in the Soufrière area, and questionnaire returns and field observations suggest that the introduced population has dispersed at least 2 km from the site of the initial introduction, a hotel on the outskirts of Soufrière. Mapping captures and reported sightings imply dispersal has been primarily along the riverine corridors of the River Soufrière and some of its tributaries, although this conclusion might reflect a sampling bias, as these lower lying areas are more readily accessible by search teams than the very steep slopes that characterize much of the area.

The alien iguanas are easily distinguished from the natives by having a larger number of more densely packed, and more prominent nuchal tubercle scales, which are, by comparison, much reduced in size and number in Saint Lucia Iguanas. In addition, the subtympanic plate that distinguishes *I. iguana* from *I. delicatissima* is much larger relative to the tympanum in the alien population, whereas the scales immediately anterior to this subtympanic plate are proportionately much larger in the Saint Lucia Iguana. The eye of the Saint Lucia iguana, at least in adults, also appears to consistently have a much darker iris than that of the alien.

Management of the Alien Iguanas

The pathway of introduction to Saint Lucia for alien iguanas appears to have been via the pet trade, as appears to be the case for all alien populations of *I. iguana* introduced into the Caribbean and elsewhere (Kraus 2009). A few individual Green Iguanas (reports vary from four to six) were held in a private collection, without a permit, in Soufrière until at least 2002 (M. Morton, pers. obs.), after having been imported, again without a permit, as hatchlings from a pet shop in Canada during the late 1980s (M. Bobb, pers. comm.). The origin of these hatchlings is unknown. Although the undesirability of these animals being held in an unsecured private collection in Saint Lucia was noted in 2002, confusion over legal instruments apparently hindered their confiscation (two remaining in captivity in 2009 were belatedly confiscated and euthanized). In early 2008, reports of free-living iguanas, adults and hatchlings, in the Soufrière area were collated and mapped. Although the founding individuals were still in captivity in 2002 (M. Morton, pers. obs.), a questionnaire of Soufrière residents collected reports of iguana sightings prior to 2000 (Krauss 2010a), suggesting that they bred in captivity and offspring apparently escaped prior to 2002 (although this has been denied by the former owners).

The current geographical separation of Saint Lucia and alien iguanas on the island and the apparently restricted distribution of the alien population could provide an opportunity for eradicating the aliens. It might also offer an opportunity to mitigate some of the risks of mixed messages in public awareness campaigns that could arise from simultaneously trying to protect one iguana population while attempting to eradicate another.

Simulations of population growth using the population viability analysis software VORTEX (Lacy 1993, Lacy et al. 2009) have led to some predictions regarding the potential success of eradication efforts[2]. Simulating a worst-case scenario of 60% juvenile mortality (i.e., the same as that estimated for adult Green Iguanas in Panama; Rand and Bock 1992) and an alien population established since 1990 (i.e., a few years after hatchlings initially were imported) predicted that extinction probabilities greater than about 30% are very unlikely — regardless of any hunting pressure we could feasibly apply (Morton 2010). By contrast, a relatively modest hunting pressure (60–180 adults or 600–1,000 juveniles removed per year) could raise extinction probabilities to almost 100% in a best-case scenario of 90% juvenile mortality and a population established for only four years (i.e., accounting only for the first recorded appearance of hatchlings in the wild. This best-case juvenile mortality is slightly lower than that reported by Harris (1982) and van Devender (1982), but those studies could not distinguish loss of juveniles through emigration and death). The same hunting pressure is predicted to increase extinction probabilities to about 80–90% for intermediate scenarios (75% juvenile mortality and/or a population established since 2002, the last year when all the known founder iguanas were confirmed to be in captivity). VORTEX simulations also predicted the most likely current alien iguana population size under the worst-case scenario to be in the tens of thousands, which is inconsistent with the difficulty of finding alien iguanas around Soufrière, suggesting, at least for the moment, that the worst-case scenario is not the most accurate representation of reality. All scenarios predict explosive population growth if unchecked by aggressive management interventions.

In 2010, the SLFD and Durrell established a four-year collaborative partnership to eradicate the alien population of *I. iguana* (Krauss 2010b). To date, however, even relatively modest hunting pressures used in the simulations described above exceed the alien iguana removal rates that we have been able to achieve in the first year of this project, despite intensive searches. At this time (late 2010), only 21 adults (including sub-adults) and 132 hatchlings have been removed. All iguana removals have been the result of intensive visual searches supplemented by reports from local residents, which led to captures by hand or pole-noose. Captured iguanas are euthanized by lethal injection administered by the Veterinary Department of MALFF. Our low capture rate is likely due to a combination of the cryptic nature of iguanas at rest in trees and an iguana population putatively at low densities. Attempts to evaluate different search and capture approaches are under way.

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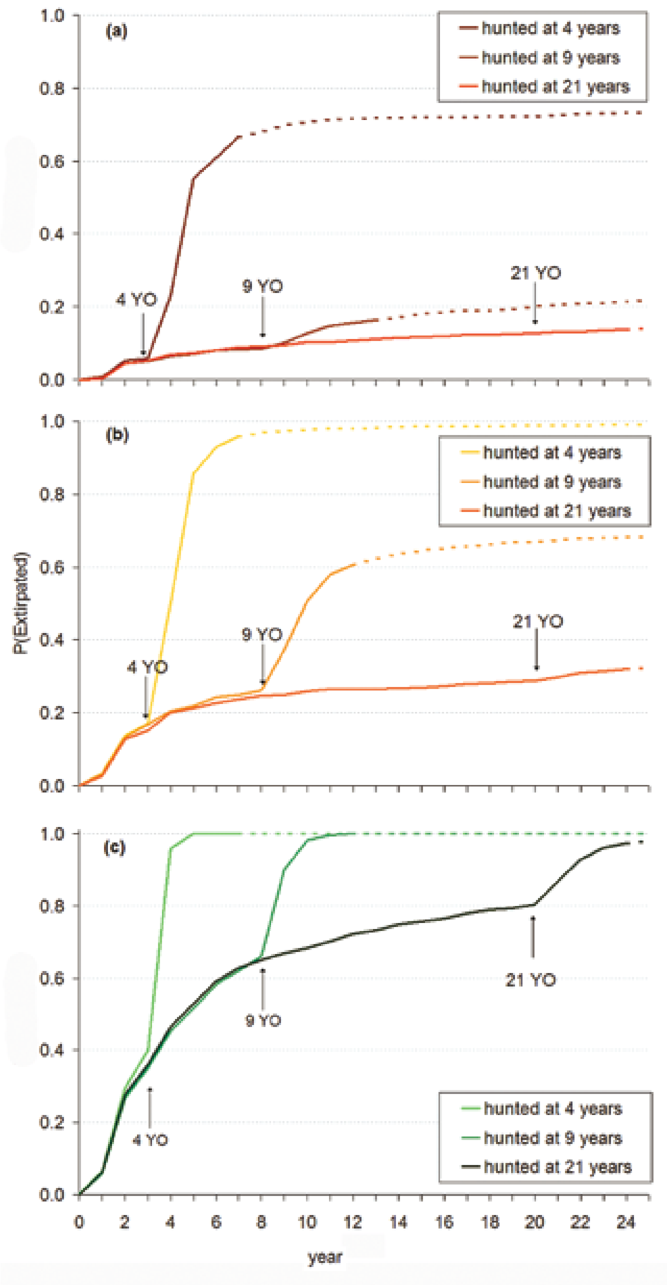
[2] Population viability analyses (PVAs) have been criticized for not providing valid predictions of extinction risk, especially over long time-scales (e.g., >100 yrs), as they assume constant ecological (and anthropogenic) processes that are unlikely (Boyce 2001). Their utility in comparing the relative effects of alternative management scenarios, however, has been noted (Boyce 2001). Another common criticism of PVAs is that all of the model parameter values are rarely known for the species being examined. As White (2000) commented, if parameter estimates are largely guesses, then model predictions are also guesses. Boyce (2001), however, pointed out that obtaining accurate estimates for all parameters is unrealistic and should not detract from the heuristic use of PVAs, for example, when comparing alternative management scenarios. For the scenarios presented here, some parameter estimates were taken from published literature on *I. iguana*. Age of first reproduction was estimated at two years, which is pessimistic when compared with Zug and Rand's (1987) estimates (but see and Pratt et al. 1994, cited in Rodda 2003). Reproduction was assumed to be polygynous (references reviewed in Rodda 2003). Adult mortality was set at 60% using Rand and Bock's (1992) estimates, and juvenile mortality was set at (as a worst case, and presumably pessimistic) the same. As a best case (and probably optimistic), it was set to 90%, as noted above. Two parameters were based on unpublished data collected by us in 2010, albeit using small samples: Sex ratio at birth was assumed to be 1:1 based on a sex ratio of 37:40 from a sample of 77 hatchlings. Mean clutch size was estimated at 40 ± 12.18 based on a sample of four gravid females in 2010. Other parameters were guesses. Percent of adults breeding was estimated as 62.7% for males (given polygyny) and 100% for females. Environmental variation was set to have no effect on breeding (i.e., no variation in reproductive success from year to year). Carrying capacity was set as high as VORTEX allows (60,000) to model unchecked growth in an expanding population. More details are provided in Morton (2010). Although all of these parameter values are uncertain, we believe they are biologically plausible (and more likely to err on the side of pessimism) — and they do allow us to model different management scenarios. As more data accumulate from alien iguana captures in Saint Lucia, we will be able to refine our parameter estimates and run further simulations. For now, they demonstrate the potential utility of this tool and allow us to simulate responses of a population the size of which is beyond our means to reliably estimate at this point.



Predicted effect of hunting pressure applied to juveniles and adults in the alien iguana population establishing in Saint Lucia. The graphs show the predicted probability that the population will be extirpated if it is experiencing: (a) Low (60%) juvenile mortality, (b) moderate (75%) juvenile mortality, or (c) high (90%) juvenile mortality in addition to the hunting pressure applied. The three lines in each graph illustrate uncertainty over how long this population has been establishing; i.e., hunting is simulated as being applied to a four-year-old population (hunting starts at point 4 YO), a nine-year-old population (at 9 YO), or a 21-year-old population (at 21 YO). For a population experiencing high juvenile mortality in addition to hunting (c), the probability of extirpation is high, regardless of how long the population has been establishing. For moderate or low juvenile mortality in addition to hunting (b, a), a high probability of extirpation exists only for the younger populations (first hunted at 4 YO or 9 YO). Simulations were carried out using VORTEX (Lacy et al. 2009); this figure was adapted from Morton (2010), who detailed the VORTEX model parameter values used in the simulations.

A pilot study in September 2009 also deployed 50 Tomahawk live traps and 20 releasing-lock snares in about 0.5 km^2 within the core area of iguana sightings, but no iguanas were captured by either method over a four-week period. Traps and snare enclosures were baited with aromatic fruit (e.g., mango, banana) plus fragments of red fabric, as iguanas are known to respond to red items such as hibiscus flowers (e.g., Alberts 2003). Our lack of success could be attributable to the arboreality of the iguanas, the putative low population density, and/or an apparent super-abundance of food (foliage), which would render the baited traps less attractive. Further trapping efforts are projected for the nesting season in 2011, which is presumably from February to early May — based on the timing of nesting in Saint Lucia Iguanas (Morton 2007) and consistent with the timing of alien hatchling captures in 2010. During this period, female iguanas presumably spend a greater proportion of their time on the ground and, post-nesting, are likely to be more motivated to feed after having suspended feeding while gravid (Rodda 2003). We also plan to pilot and evaluate the use of detector dogs to locate alien iguanas in 2011. Detector dogs have been used to locate another alien invasive arboreal reptile, the Brown Tree Snake (*Boiga irregularis*) on Guam, both in airport cargo (Vice and Engeman 2000) and free-living in trees (Savidge et al. 2008).

Given the allopatric distribution of the two iguana populations on Saint Lucia, we believe that no hybridization has yet occurred. Tissue samples from both populations have been banked in order to search for alleles unique to the alien population. These will allow us to survey the native population for evidence of introgression. Although the alien iguana population currently appears to be restricted to a relatively small area in Saint Lucia, it is reproducing and will presumably increase its range. Krysko et al. (2007) suggested that a population explosion of alien *I. iguana* in Florida followed Hurricane Andrew in 1992. Possible effects of Hurricane Tomas on Saint Lucia in October 2010 are unknown. The Soufrière area was among the worst affected by severe flooding and extensive landslides. Alien iguanas, both adults and young of the year, however, have been captured in the core area since Tomas struck. As with many other invasive species, reptilian invasions are often characterized by an extended lag period, sometimes lasting decades, which precedes an explosion in numbers and range (e.g., Krysko et al. 2007, Kraus 2009). Questionnaire returns from 2009 and 2010 suggested that the alien iguana population in Saint Lucia might now be moving, or about to move, beyond this lag period into a period of rapid growth. Efforts to eradicate the alien iguana population must include strategies for preserving the Saint Lucia Iguana in the face of ongoing threats emanating from the possibility of contact with the alien iguana population.

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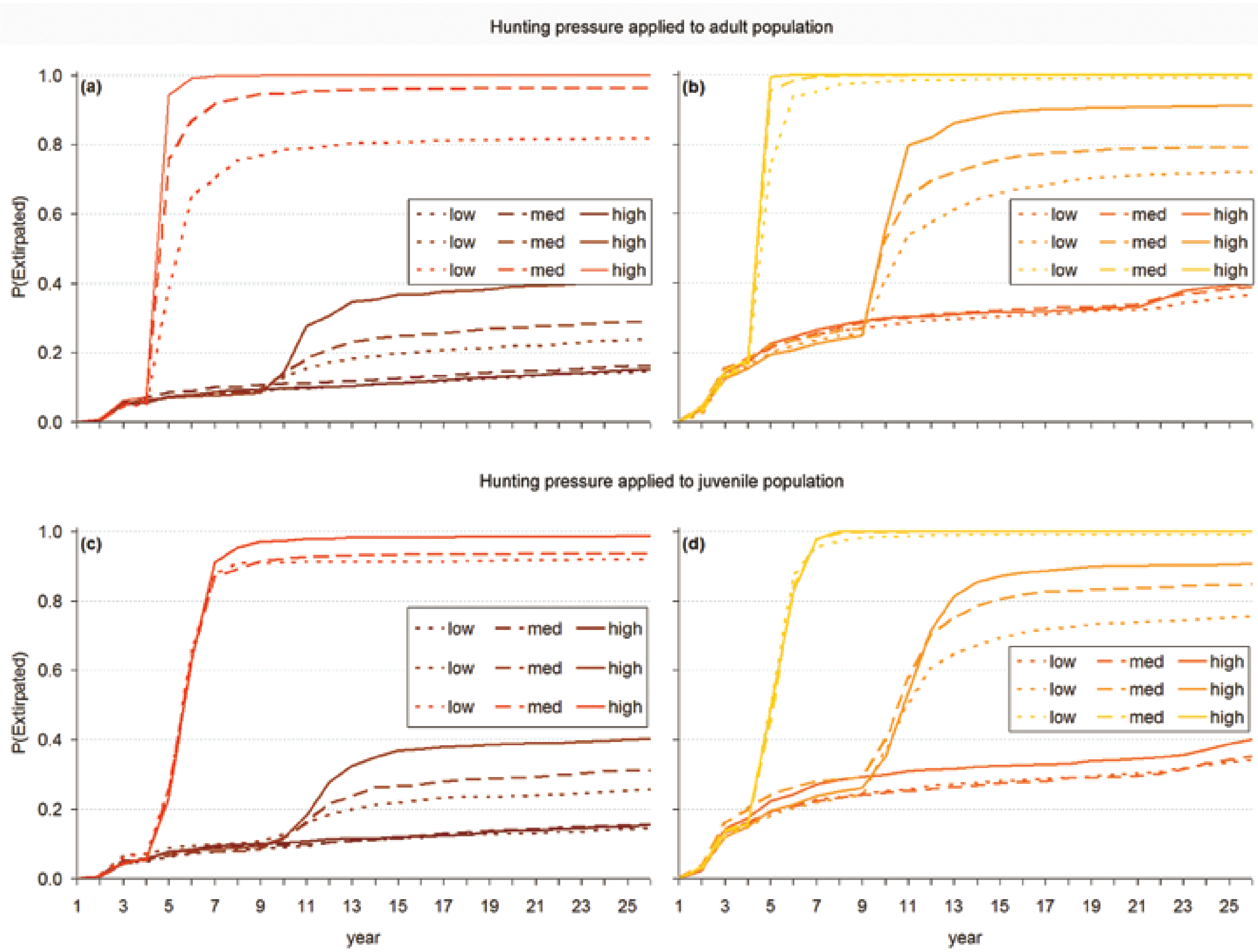

Predicted sensitivity to extirpation of the alien iguana population establishing in Saint Lucia depending on whether hunting pressure is applied to the adult population (a, b) or the juvenile population (c, d). Populations experiencing low juvenile mortality in addition to hunting (a, c) and moderate juvenile mortality (b, d) are shown. For populations with high juvenile mortality, the probability of extirpation under hunting is high in all cases. Simulations were carried out using VORTEX (Lacy et al. 2009); figure adapted from Morton (2010).

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Male Saint Lucia Iguana (*Iguana* cf. *iguana*). This individual is known to have been killed for food by hunters at Grand Anse Estate the year after this photograph was taken.


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A burned wetland at Palo Verde National Park, Costa Rica; note the aggregation of dead Scorpion Mud Turtles (*Kinosternon scorpioides*) in the foreground.

Reading the Ashes: Arson Decimates a Tropical Wetland, But Allows New Observations of a Neotropical Mud Turtle

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All photographs by the senior author.

During a National Science Foundation-funded summer research program for undergraduates, we witnessed the loss of more than 5,000 ha of prime semi-fossorial turtle habitat near Catalina Station, Palo Verde National Park in Guanacaste, Costa Rica. According to park officials, the fire was set intentionally by poachers to allow access to wildlife from the Tempisque River, which borders the park. Natural wildland fires can be devastating, but also beneficial for a local ecosystem; however, human-induced fires are generally more destructive due to lack of perimeter controls and heavy fuel loads. Wetland fires are especially damaging because of the loss of habitat and individuals from species that are not adapted for fast overland motility. Although Cattails (*Typha* sp.) are exotic in this region, they provide habitat for a number of native species, including semi-fossorial turtles. The fire provided a unique opportunity to view a wetland community that we would otherwise have been hard pressed to observe.

As the fire still smoldered in the Área de Conservación Arenal Tempisque, we made a preliminary hike around the southern perimeter of the fire. The landscape was dominated by hundreds of Black Vultures (*Coragyps atratus*) and Crested Caracara (*Polyborus plancus*) feasting on the

An irruption of Black Vultures (*Coragyps atratus*) that arrived to pick up the pieces following the fire.

Remains of Scorpion Mud Turtles (*Kinosternon scorpioides*) consumed by fire at Palo Verde National Park. The individual in the upper right had partially buried itself during the fire.

remains of turtles and other wildlife killed by the fire. The putrid combination of smells from burned flesh, ash, and wetland sludge hung in the air and clung to our clothes. The visual scene was no more appealing; an astonishing abundance of dead turtles was clearly visible even from beyond the border of the fire zone. So dramatic was the effect that front pages of local and national papers included an image of a burned turtle (Campos and Arroyo 2008).

Background

Palo Verde National Park is located 28 km south of Bagaces, Costa Rica in the Tempisque Basin. The park consists of more than 13,000 ha of floodplain, marshes, limestone ridges, and seasonal pools in the middle of the driest region in Costa Rica. Palo Verde serves to connect to two other reserves, the Dr. Rafael Lucas Rodriguez Caballero Wildlife Refuge and the Lomas Barbudal Biological Reserve. The swamplands that connect Palo Verde to the other reserves are threatened by local entrepreneurs who have invested in permits to clear the swamp forest and plant crops, which would further increase the isolation of these reserves (Baker 2004).

The region experiences distinct wet and dry seasons. The lack of precipitation from roughly November to March causes the region to become very dry. During this period, some farmers will intentionally start fires in order to clear land for their crops. In this region, if land is cleared of forest by natural causes, it is essentially open to farming. Additionally, poachers set fires to improve access to certain coveted wildlife species.

Palo Verde and its surrounding reserves have 15 different habitats, including several types of swamps and marshlands. These habitats provide for a wealth of species diversity ranging from White-tailed Deer (*Odocoileus virginianus*), White-nosed Coati (*Nasua narica*), and American Crocodile (*Crocodylus acutus*) to endangered species including the Great Curassow (*Crax rubra*), Yellow-naped Parrot (*Amazona auropalliata*), and King Vulture (*Sarcoramphus papa*).

Prescribed fire is a beneficial management tool that can maintain or restore desired, historic ecological conditions (e.g., Brockway and Lewis 1997, Carter and Foster 2004). Prescribed burning has become a primary tool of ecosystem restoration in the United States because of the benefits and historical association of fire in some ecosystems (Johnson and Hale 2002). With such an increase in the use of prescribed fires, understanding the effects on wildlife became increasingly important (Ford et al. 1999). Unfortunately, little information exists about the effects of prescribed fire on amphibians and reptiles (McLeod and Gates 1998, Ford et al. 1999, Greenburg et al. 1994, Pilliod et al. 2003). Although some obvious and immediate declines of amphibian and reptilian populations will occur during a wetland fire, vegetative recovery and restructuring might provide better habitat for individual populations — a subject in need of more study.

Recording the Effects

We documented turtles and other species within and around the fire zone by utilizing standardized transect sampling methods. We also attempted to determine turtle densities in different areas of the fire zone by using a stratified-random study design. The fire zone was classified into three categories: (1) Close to the ignition point, (2) close to the terminus of the fire, and (3) an intermediate area. Within each zone, we randomly selected three 1,000 x 1,000-m study plots. Within each plot, we counted turtles within five 300-m transects.

We expected to find an assemblage of turtle species in the wetland, but the Scorpion Mud Turtle (*Kinosternon scorpioides*) was considered the most likely to occur. It ranges at low elevations from southern Tamaulipas, México, southward to northern Argentina, Bolivia, and northern Perú (Ernst et al. 1992). This species is omnivorous and will eat fish, snails, amphibians, insects, algae, and other plants (Vanzolini et al. 1980). It has a high-domed carapace that can measure up to 17.5 cm in length. The carapace has three well-developed longitudinal keels and is an unmarked brown to black in color. The plastron has a single movable hinge between the pectoral and abdominal scutes. The plastron might not be large enough to completely protect the animal when closed (Ernst et al. 1992, Berry and Iverson 2001).

One subspecies of Scorpion Mud Turtle, the Red-cheeked Mud Turtle (*K. s. cruentatum*), was the only turtle observed in the fire zone or adjacent areas. Turtles occurred at a density of 6.33 turtles/transect or 316.5 turtles/ha. This was similar, but slightly greater than the 254 turtles/ha reported by Medina et al. (2007) for another subspecies of *K. scorpioides* (*K. s. albogulare*). In temperate regions, Gibbons (1983) reported 56 *K. subrubrum*/ha and Bonin et al. (2006) reported densities for several species of mud and musk turtles, including 260 turtles/ha for *K. subrubrum*, 229

Additional species killed in the fire zone included Northern Tamandua (*Tamandua mexicana*; A), White-lipped Peccary (*Tayassu pecari*; B), White-nosed Coati (*Nasua narica*; C), and Boa Constrictor (*Boa constrictor*; D).

One of the few Scorpion Mud Turtles that survived the fire, its shell slightly charred, but otherwise unscathed.

turtles/ha for *Sternotherus carinatus*, and 194 turtles/ha for *S. odoratus*. No density estimates were available for *K. s. cruentatum* in other areas.

No significant differences (one-way ANOVA, F = 0.08, P = 0.10) existed in the numbers of turtles observed among site categories, suggesting that turtles did not make large movements away from the ignition point. Mud turtles might be particularly susceptible to fires due to an adaptation to seasonal dry weather; they often burrow in the mud until the next rain (Ernst et al. 1992). This adaptation could be one explanation for why so many mud turtles were killed in the Palo Verde marshland fire. Perhaps they did not try to escape the fire, but instead simply tried to burrow into the sediments. However, Teska (1976) reported substantial movements of turtles in Guanacaste Province during the dry season.

Additional species killed in the fire zone included Northern Tamandua (*Tamandua mexicana*), White-lipped Peccary (*Tayassu pecari*), White-nosed Coati (*Nasua narica*), and Boa Constrictor (*Boa constrictor*) along with several unidentifiable snake species. Other sources (Campos and Arroyo 2008) also listed the Gray Fox (*Urocyon cinereoargenteus*). Documentation of such mobile species and accounts from park officials suggest that the fire was extremely fast-moving. However, these species might have tried to climb or burrow in unsuccessful attempts at escaping the fire. Interestingly, no crocodilians were observed in the fire zone.

While the loss of individuals due to this act of arson cannot be overstated, the insight into turtle communities provided by this research increases park managers' knowledge of the herpetofauna. According to Savage (2002), "very little is known of the life of this common species" (Red-cheeked Scorpion Mud Turtle). Also, during our final transect, we recorded the only living turtles that were observed during our entire time at Palo Verde National Park. Three Red-cheeked Mud Turtles made their way along the fire line, their shells slightly charred, but otherwise unscathed. By the end of our study, fresh green sprouts were already erupting from the ashes. Moll (1990), Gibbons et al. (1983), and Pritchard and Trebbau (1994) suggested that Scorpion Mud Turtles could rapidly move into different areas in response to drought and habitat availability. The outlook for reestablishing the turtle population in this area appears to be very positive.

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COMMENTARY

The Mass Extinction of Scientists Who Study Species[1]

Craig McClain[2]

We are currently in a biodiversity crisis. A quarter of all mammals face extinction, and 90% of the largest ocean fish are gone. Species are going extinct at rates equaled only five times in the history of life. But the biodiversity crisis we are currently encountering isn't just a loss of species, it's also a loss of knowledge regarding them. Scientists who classify, describe, and examine the relationships between organisms are themselves going extinct. The millions of dollars spent globally on technology to catalog species may actually be pushing out the people we rely upon: Taxonomists and systematists. We're like young children frantic to add new baseball cards to our collections, while the actual creators of the baseball cards themselves are vanishing.

Take, for example, the aplacophorans, a rare, rare group of invertebrates closely related to octopuses, squids, snails, and clams. Most of us will never see even one of the approximately 360 known species of small (less than a couple of inches long) aplacophorans that inhabit ocean depths greater than 50 feet — but ignorance of this group is not limited to the public. Fewer than two dozen scientific papers have been published on the group since 2005, even though many new species await discovery and description — and most of these studies were done by one scientist, the venerable Amélie Scheltema of Woods Hole Oceanographic Institute. As she edges closer to retirement, she may sadly become the last to study aplacophorans. If 50% of the species of aplacophoran went extinct tomorrow, we would never know.

Amelie's story is tragically common. Martin Sørensen of the Natural History Museum of Denmark is one of the very few active kinorhynch, or mud-dragon, taxonomists. Martin also represents one of only two living taxonomists who have studied gnathostomulids. The other, Wolfgang Sterrer, is retired. Both kinorhynchs and gnathostomulids are small, less than one-tenth of an inch in length, and dwell between grains of sand and mud on the ocean floor. Fewer than 300 species are described from both of these phyla — the broadest classification into which scientists group animals — and our knowledge of them is based almost entirely on collections from the well-explored eastern coast of the United States, the Mediterranean, and the western coast of Europe.

"Even within these areas, new species appear quite often, and when I collect outside [these areas], I always expect to find undescribed taxa exclusively," Sørensen wrote in a recent e-mail to me. His new work in the East China Sea has already uncovered 15 new species. Indeed, the morning he e-mailed me, Sørensen, looking through his microscope, had just discovered another new species. "The number of taxonomists working on these obscure taxa has always been rather low (which explains our limited knowledge about them), but within the last 20 years taxonomy as a discipline has come under even harder pressure which has resulted in a further decline in the number of experts," Sørensen wrote.

This problem plagues well-known groups, too. For example, nematodes represent more than 28,000 described species of freshwater, marine, terrestrial, and parasitic roundworms. On the seafloor, they account for 85–95% of all organisms. However, a new study found the number of scientific papers describing new nematode species is half of what it was

The dearth of taxonomists and systematists is not as dire for terrestrial vertebrates as for invertebrates. Nevertheless, ongoing new discoveries of mammals, birds, reptiles, and amphibians previously unknown to science provide ample evidence that we might be undermining our efforts to protect biodiversity by not supporting efforts that encourage young scientists to learn and implement the skills necessary to generate essential knowledge of life's diversity before it disappears. This and the following images feature four U.S.-based scientists actively involved in the taxonomy and systematics of amphibians and reptiles. Janalee P. Caldwell, of the Sam Noble Oklahoma Museum of Natural History and Department of Zoology, University of Oklahoma, in a field camp in Brazil. Amazonia and the Neotropics in general harbor a plethora of undescribed species. Caldwell described the dendrobatid *Hyloxalus chlorocraspedus* in 2005. Males serve as the parental frog, carrying as many as ten tadpoles on their backs before releasing them into small forest pools shortly before metamorphosis.

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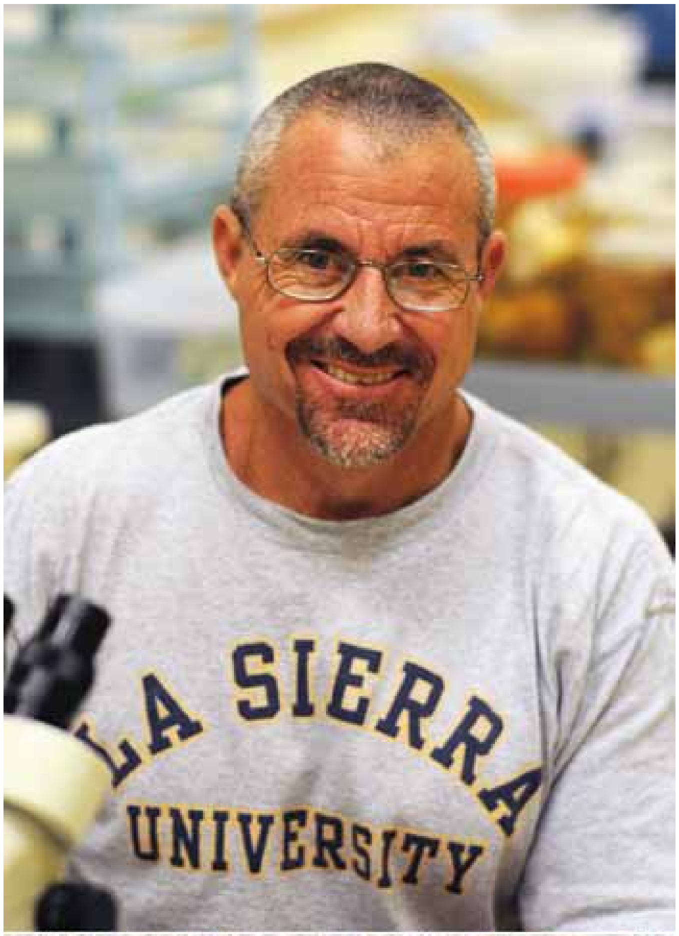
[1] Adapted with permission from <www.wired.com/wiredscience/2011/01/extinction-of-taxonomists/> (posted 19 January 2011).

[2] Craig McClain is assistant director of science for the National Evolutionary Synthesis Center and has conducted deep-sea research for 13 years, participating in dozens of expeditions in the most remote regions of the Pacific and Atlantic oceans. McClain focuses on the ecological and evolutionary drivers of marine-invertebrate biodiversity and body size, mostly in deep-sea systems. He often explores the consequences of food limitation on biological systems. McClain is also the chief editor of the award-winning science blog, Deep-Sea News.

a decade ago, and a third of the decade before that. Anywhere between 10,000 and 100,000 species remain undescribed.

Why the loss of taxonomists? We have devalued their contributions, both monetarily and scientifically. Some attribute the decline of these researchers to the replacement of outdated methods that would not meet the scrutiny of science today. These critics envision taxonomists as lone



L. Lee Grismer, of La Sierra University in Riverside, California, in collaboration with his son and a number of national scientists, has described over 70 new species in the past six years, all from southeastern Asia and many of those from the Malay Archipelago. The aptly named *Cnemaspis psychedelica* is an insular endemic known to occur on only one of 92 poorly explored Vietnamese islands that are beginning to show a surprising degree of endemism and diversity. This discovery clearly suggests that, despite recent work, the herpetofaunal diversity of the region is barely known.

Rafe Brown (top right), of the Natural History Museum and Biodiversity Institute, University of Kansas, with graduate students in the Philippines. *Hylarana* (formerly *Rana*) *tipanan* (center) was described by Brown and colleagues in 2000; when its IUCN Red List status was assessed in 2004, the species was determined to be Vulnerable due to a highly fragmented distribution attributable largely to a continuing decline in the extent and quality of its forest habitat on Luzon in the Philippines. The discovery of a 2-m-long lizard (bottom) in the forests of the Philippines speaks clearly to the lack of current knowledge of the archipelago's biodiversity, even as its forests are declining at an alarming rate. *Varanus bitatawa* is one of only three known species of frugivorous (fruit-eating) monitor lizards in the world. E.O. Wilson (1992. *The Diversity of Life*. W.W. Norton & Co., Inc., New York) asked: "Will it ever be possible to assess the ongoing loss of biodiversity? I cannot imagine a scientific problem of greater immediate importance for humanity. Biologists find it difficult to come up with even an approximate estimate of the hemorrhaging because we know so little about diversity in the first place. … we do not know the vast majority of species of organisms well; we have yet to anoint so many as 90 percent of them with scientific names."

museum scientists surrounded by dusty wood cabinets and bottles of formaldehyde where species description is more art than science — but this portrayal overlooks the suite of modern genetic methods that those interested in discovery and description of new species use with increasing frequency.

JESSICA KNUTH

S. BLAIR HEDGES

S. Blair Hedges, in his laboratory at Pennsylvania State University, has focused most of his attention on the West Indian herpetofauna, which has grown from 585 known species in 1991 to well over 700 today — with as many as 1,000 species possible — if they are discovered and described before falling victim to development (most attributable to the tourism industry), deforestation, and invasive species. The world's smallest known species of lizard (*Sphaerodactylus ariasae*, from the southwestern Dominican Republic) and the smallest known snake (*Leptotyphlops carlae*, from Barbados) both occur in the region.

This new breed of taxonomists includes Chris Mah of the Smithsonian National Museum of Natural History and Adrian Glover of the Natural History Museum in London, who are among the world's leading experts on sea stars and marine worms, respectively. Both demonstrate that the most informative science comes from synthesizing genetic techniques with more classical taxonomy based on knowledge of the anatomy and natural history of organisms.

Extinction of taxonomists continues despite a growing pool of funds for biodiversity programs and databases. EUNIS, EOL, OBIS … the list goes on. These databases have pooled our collective biodiversity knowledge, helping identify what drives biodiversity and set conservation priorities. Thankfully (my own research has relied upon them), thousands of hours and millions of dollars have been spent on these initiatives. However, many of these programs did not financially support taxonomists generating the data these databases required.

After a decade and 650 million dollars, the Census of Marine Life represents one of the largest initiatives to document biodiversity on our planet. In some regards, it was a great success, supporting 2,700 scientists to produce 2,600 new scientific publications and thousands of new species descriptions. But as the Census ends this year, no agency or organization is offering to fill the funding void previously filled by the Alfred P. Sloan Foundation. Perhaps more importantly, the Census, like many initiatives, did not provide long-term positions and appointments for those doing taxonomic work. Many biology departments within universities no longer employ a taxonomist. The remaining positions are relegated to museums.

Why? As Sørensen explains, "The declining number of taxonomists and systematists is at least to some extent linked to the fact that your scientific production today should be measurable." The units of measurement are collected grant money or the impact factor of a journal paper. Taxonomy has never been considered hot, and pure taxonomic studies are rarely funded, he wrote. Departments need grant money to operate.

Science as an institution may also be partly responsible for undercutting taxonomic work. Although a crude metric fraught with several issues, we measure the impact of a scientific paper by how many times other scientific papers have cited it. Similarly, we measure the impact of scientists by counting their cumulative citations. Unfortunately, taxonomic work is rarely cited, even when it should be.

On the other hand, the brilliant biodiversity databases we have created lead to a plethora of scientific papers. The Paleobiology Database, a comprehensive online catalog of fossil species, has already generated more than 100 publications. But the requirement for using this database, like most others, is citation of the database itself, not the nearly 35,000 papers generating the original data.

The decline in taxonomists means that at some point in the future we will be unable to train new generations of taxonomists. This problem is recognized by the National Science Foundation, which in 1994 created a program to enhance taxonomic research. While this initiative provides training, it does not create job opportunities. Other problems are taking form too. For example, in 2006, I set out to explore how biodiversity and body size were linked among animals. To do so I needed information on the largest- and smallest-sized species for each group of animals — something surprisingly not readily garnered from the published literature. I relied on my connections with taxonomists for guidance and information, but for many groups I struggled to find a contact. Even for well-known animals, I was amazed by how few scientists still studied them. My personal experience highlights how progress in biology as a whole may be impeded if we lose taxonomy. The problem we face is a loss of knowledge not yet recorded in the scientific literature. In our technological efforts to concentrate our biodiversity knowledge, we may be rendering a field and body of knowledge obsolete — and, in the process, we may be undermining our own efforts to protect biodiversity.

ELIZABETH WRIGHT

The deteriorating relicts of human presence on Sombrero have been effectively integrated into the natural ecosystem.

TRAVELOGUE

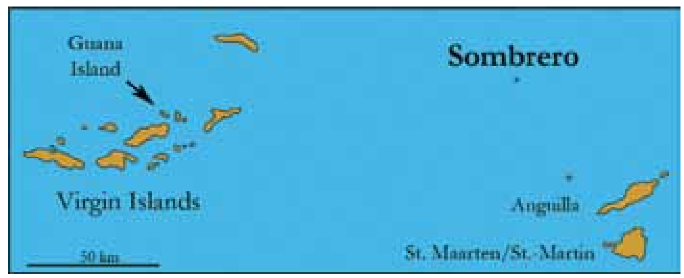
Sombrero: Lizards Among the Ruins

Elizabeth Wright

Department of Forestry, University of Missouri, Columbia, Missouri

This is an interesting time to be alive. Humans are running out of land and constantly searching for new opportunities to fuel economic growth. At the same time, we see a growing awareness of the natural environment, the resources it provides, and the harmful effects of human population growth on the Earth's other species. Some people deny that a problem exists and suggest that we should continue as we are. Others believe that we should park our cars, move into the woods, abandon technology, and become one with nature. Most of us fall somewhere between those two extremes. I believe that we must learn to coexist with nature while finding a way to foster economic growth without destroying our planet. I am fascinated by that goal and think that the first step is in understanding what is at stake. How can we coexist with nature if we remain ignorant of her components? I had an opportunity to witness a few implications of this age-old paradox during a recent visit to Sombrero, a tiny island about 60 km north of Anguilla.

On a fine morning in October 2010, I was one of a team boarding the aptly named *Ocean Girlz*, a catamaran chartered by The Conservation Agency for a trip to Sombrero. Sombrero is unique. Rising out of the ocean some time in the early Pliocene, it is about 1.5 km long and about 0.4 km at its widest point and has never been part of another body of land. Sombrero is the northernmost of the Lesser Antilles, and is part of the nation of Anguilla. Life on the 38 ha of marly limestone arrived by migrating from the mainland or smaller islands on floating debris, by flying, or



JOHN S. PARMERLEE, JR.

As the northernmost of the Lesser Antilles, Sombrero is a long way from everywhere, sitting on its own island bank and never connected to any other landmass.

ROBERT POWELL

Sombrero is one of three Lesser Antillean islands that harbor black Ameivas. In addition to *Ameiva corvina* (named after equally black crows), *A. corax* lives on Little Scrub Island off the northeastern coast of Anguilla, and *A. atrata* lives on Redonda, another isolated "rock" emerging from the sea.

ROBERT POWELL

Access by ladder is necessary for scaling the sheer walls of the island, limestone cliffs shooting 12 m straight up out of the water.

GAD PERRY

The anoles of Sombrero are very similar to *Anolis gingivinus*, which is ubiquitous on the Anguilla Bank. Genetic studies will determine if they are the same species.

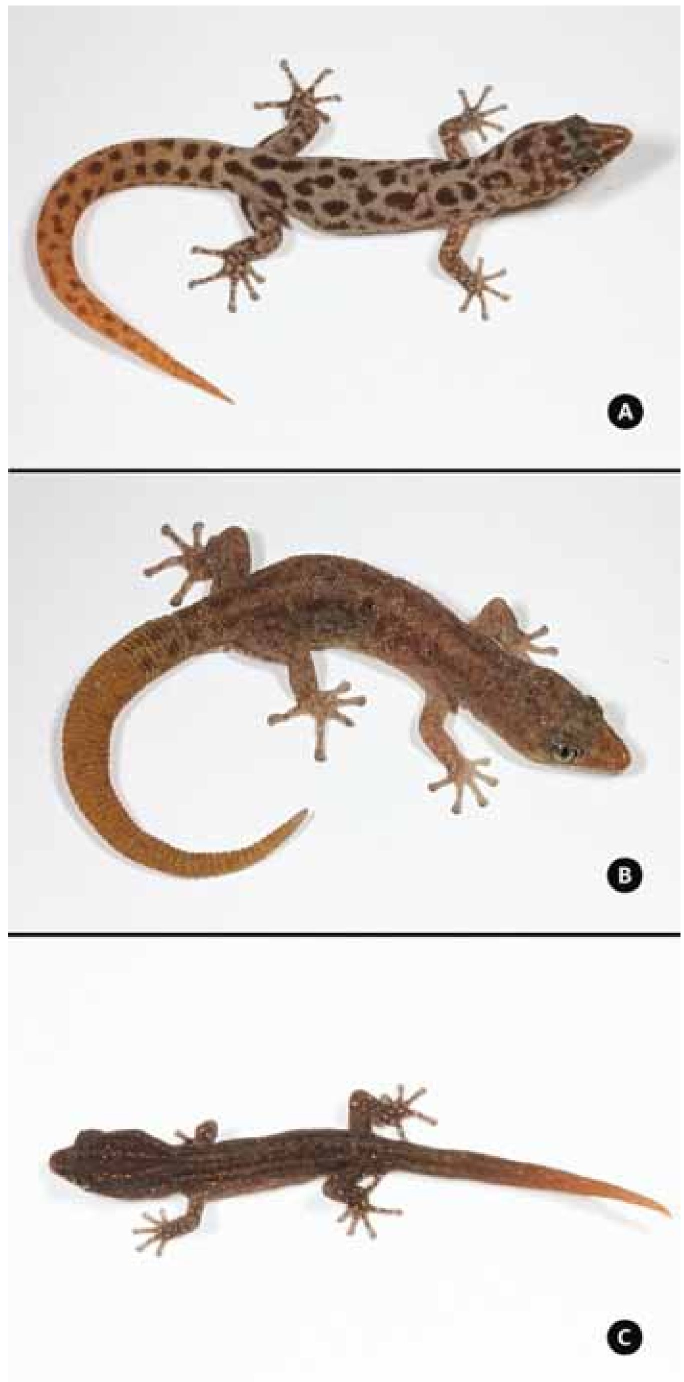
Island Girlz, here anchored off Sombrero, made the expedition to the island a comfortable experience — although the captain had not previously been to Sombrero.

A Brown Booby (*Sula leucogaster*), silhouetted against the sunlit sky on what looked like a rusty loading crane, greeted our arrival.

Although proficient scavengers when birds or people provide welcome meals, the Ameivas of Sombrero usually have to dig and root for food.

being carried by storms, birds, or humans. The island is frequently deluged by giant waves, and might be entirely submerged during severe hurricanes. Such conditions make it hard to get there and even harder to survive. The resulting founder effect — the sometimes considerable impact that the few founding individuals can have on later generations — dramatically increases the chance of endemism (Ivie 1999). This is why we were going to Sombrero.

The trip was organized by Dr. Robert Powell, a herpetologist at Avila University, who wanted to learn more about the lizards of Sombrero. Dr. James Lazell, the president of the Conservation Agency, had visited the island in 1963 and had discovered that three species occurred on the island (not just the one that had been previously reported): An anole currently identified as *Anolis gingivinus*, the common species on the nearby Anguilla Bank; a Dwarf Gecko, which Lazell described as *Sphaerodactylus* "near" *sputator*, the species that occurs on both the Anguilla and St. Christopher banks; and the spectacular black Ground Lizard, *Ameiva corvina* (Lazell 1964). In



The Dwarf Geckos on Sombrero exhibit variable patterns, some spotted, some almost unicolored, and others with stripes, as seen on these two adults (A/B) and one juvenile (C).

The powerful claws on the forelimbs of Ameivas are ideally suited for rooting and digging for food.

The author, with aspirator in hand, searches for small arthropods among the ruins.

the 1960s, when Dr. Lazell visited Sombrero, no one was yet dreaming of the secrets that DNA might one day reveal, and tissues collected during a survey by Dr. Jenny Daltry (1999) were subsequently lost. The time had come to collect some more samples so that the relationships and perhaps true identities of these lizards could finally be established. Our team also included Dr. Gad Perry, a conservation biologist at Texas Tech University, Dr. Wenhua Lu, an entomologist with the Conservation Agency, and Susan Valentine-Cooper, an experienced entomologist, who, like me, had been invited to come along and help collect small arthropods.

So, there we were aboard *Ocean Girlz,* on our way from Guana Island in the British Virgin Islands, where we were conducting long-term research projects, to Sombrero. I was in awe of the flying fish as they exploded out of the water and soared for what appeared to be hundreds of meters across the waves. As we approached the island some three hours into our voyage, we saw a small vessel anchored near the ladder that provides access to the island. Access by ladder is necessary for scaling the sheer walls of the island, limestone cliffs shooting 12 m straight up out of the water. I almost fell into the water on my first attempt to step from the bow of our catamaran, moving up-and-down with the waves, onto the ladder, and was saved only by the quick action of the crew. My second attempt was successful and I climbed up, the metal hot under my hands.

Migratory Blackpoll Warblers (*Dendroica striata*) darted about, searching for the same insects we were trying to collect (A). These tiny birds, which began their voyage in the northeastern United States, had flown over open ocean for days. Totally spent, some individuals unlucky at making their first landfall on a desolate island like Sombrero, were unable to scrounge for sparse food in time to fend off exhaustion and death (B). Although unfortunate for the birds, the Ameivas readily scavenged the carcasses (C).


GAD PERRY

Windows in the ruins of the old lighthouse keeper's quarters look out over the desolate landscape of Sombrero to the Atlantic Ocean beyond.

The other boat had carried the immigration official from Anguilla who was to meet us and check our passports. I was nervous as I approached the top of the ladder, expecting a large Anguillian official with a scowl. What I encountered at the top of the ladder, however, was the most non-threatening immigration officer I could imagine. He was slender and wore a straw hat, a loose-fitting button-up shirt, and khaki pants, and he was sweating and smiling and settled on a rock. We gave him our passports, he verified that we were who we said we were, and began his long journey home. We turned to take in our surroundings.

The landscape was desolate. Not a tree in sight, just viney plants criss-crossing the rocks. Overhead, a Brown Booby (*Sula leucogaster*) was silhouetted against the sunlit sky on what looked like a rusty loading crane. Black Ameivas were abundant, scurrying a bit when we got too close. Magnificent Frigatebirds (*Fregata magnificens*) hovered in pockets of hot air, their red throat sacs flapping a little in the wind. Migratory birds, mostly Blackpoll Warblers (*Dendroica striata*) darted about, searching for the same insects I was intending to catch.

Despite its relative isolation, humans have had a considerable impact on Sombrero. Old rusty metal structures jutted up all over the island. Giant pits in the limestone peppered the otherwise flat terrain, testament to 19th-century American and British mining operations that quarried considerable volumes of phosphates (mineralized guano) for use as fertilizer in an effort to resuscitate the soils of the southern states that had been exhausted by the plantation system. They even blew up whole sections of the hat-shaped island until only the brim remained (Pappalardo 2001). However, this was not the only time the island was threatened by human activities. In 1999 and 2000, Beal Aerospace of Texas was considering Sombrero as a potential launching site for rockets carrying commercial satellites into space. Triggered by resistance from bird enthusiasts who claimed that Sombrero was an important nesting site for many West Indian species, Beal conducted an environmental assessment that claimed that the nesting site was not that important and that only one species of lizard lived on the island — and that the rockets would not affect them. Beal ultimately decided not


GAD PERRY

Ravaged by 19th-century mining activities and eroded over time by rain and waves of water violently washing over the island, the surface of Sombrero is a maze of sharp and porous "dog-tooth" limestone.

GAD PERRY

One of the larger mining pits, relicts of 19th-century efforts to extract mineralized phosphates (guano) that had accumulated over the centuries courtesy of innumerable generations of nesting seabirds.

ELIZABETH WRIGHT

Catching elusive little geckos in the rubble of Sombrero was not always successful. In this instance, however, the broken tail will provide DNA for genetic studies to determine if the Dwarf Geckos of Sombrero are "near" *Sphaerodactylus sputator*, as Lazell (1964) indicated. The lizard escaped and will regenerate a new tail.

ROBERT POWELL

During the heat of the day, nesting Brown Boobies (*Sula leucogaster*) lifted their bodies off their eggs to prevent overheating. Squawking a bit if we approached too closely, they were otherwise indifferent to our presence.

to use Sombrero, not because of the destructive nature of the project but because the weather was not to their taste (Pappalardo 2001).

The island's guano deposits were exhausted by 1890, leaving "dog-tooth" limestone that is sharp and porous, eroded over time by rain and waves of water violently washing over the island. I was very aware of how exposed my feet were in Chaco sandals. Despite the apparent desolation, I knew the island was teeming with creatures. "Well, we don't have much time," Dr. Powell said, awakening me from my state of awe. "Let's start collecting." Drs. Powell and Perry went off in search of lizards. "Catch 'em if you can, ladies!" Dr. Perry called, referring to lizards, of course, as he trudged in the direction of the lighthouse.

The entomology team started collecting. Typically, we beat vegetation and catch falling insects in our nets below or sweep through grasses with

ELIZABETH WRIGHT

ROBERT POWELL

ROBERT POWELL

The abundance of down-covered Booby chicks testified to the dearth of predators on an isolated island.

ELIZABETH WRIGHT

On a food-limited island, lizards must actively search for meals. This Ameiva was foraging through the remains of a Booby nest in search of food.

nets — but Sombrero has no tall vegetation. So, we started turning over rocks and pieces of rusty metal. We would be prepared with our aspirators — devices involving a small plastic jar equipped with tubes to suck up little critters. A rubber cork in the jar has two curved metal tubes sticking out either side, a short one with a screen that leads into the jar that is connected to a long rubber tube that you suck with and a longer one that is placed near the insect you want. You suck in and the insect is vacuumed into the jar (and not into your mouth because of the screen). I tried looking under rocks all over the island, but insects were few and far between — until we climbed down into one of the mining pits, where I found something that I had not seen — huge congregations of tiny mites. Perhaps they were in the pit because the temperature was lower or perhaps the pockets and crevices retained a little moisture.

After little success while flipping rocks, I started picking apart some of the small plants and, lo and behold, I found webspinners (order Embioptera). Webspinners are very cool primitive insects with silk glands used to spin the galleries in which they live. I ruthlessly sucked them up with my aspirator. I also looked through an old booby nest, where I found several beetle and fly larvae. I sucked those up, too — assisted by an *Ameiva* with whom I gladly shared the trove of insect larvae.

Already sunburned and with little time left on the island, I decided to explore some of the buildings. The lighthouse, built in 1868 after a ship had run into the island in 1859, was in ruins. Even after mining operations were abandoned, the British Board of Trade maintained the lighthouse to guide ships through the Anegada Passage. In 1960, a hurricane destroyed the lighthouse, which was replaced and has gone through several incarnations since. It was automated in 2002, but left a history clearly portrayed by the decaying ruins.


GAD PERRY

The concrete base of the old lighthouse and the remains of the lighthouse keeper's quarters stand side-by-side with the new automated lighthouse.


ROBERT POWELL

This Sombrero Ameiva had just excavated a beetle grub.

Lacking trees, typically the favored habitat of West Indian anoles, the anoles of Sombrero lived on rock faces or the deteriorating ruins — the only vertical habitats available on the island. This male (A) and female (B) were on poured concrete walls near the lighthouse.

Despite their ghostly appearance, the buildings have been integrated into the island's ecosystem. As I entered what was left of one of the old staff houses, I encountered two large Ameivas — and one had something yellow and insect-like hanging out of its mouth. I crept closer, determined to steal their snack. The lizards scurried under a pile of plywood planks. As I carefully lifted them, the Ameivas slipped out a doorway with empty mouths, leaving a yellow and brown scorpion that lay lifeless and stingerless on the plank. I collected it immediately.

I wandered into another building and saw an anole on the windowsill with something in its mouth. I was very confident now, and edged closer — but the anole was more skittish than the more relaxed ground lizards and it sprinted down the wall, across the floor, and under a large loose tile. I tiptoed closer and slowly started to flip the tile. The lizard ran out but left his lunch, a lively cricket. I grabbed it before it hopped away and slipped it into the plastic bag with the deceased scorpion. I thanked the lizards and apologized for stealing their lunches before heading back to where the others had gathered.

As the last specimens were being collected, I decided that I needed to catch my first lizard. What better place to do it than on an island literally crawling with hundreds of imperturbable black lizards? I crouched low to the ground and waited patiently as the lizards drew nearer. As soon as I reached out to grab one, however, it would dash out of the way. Dr. Perry approached and asked if I wanted a little help. He handed me a noose. "Just stick the noose near the head and pull up — pretty complicated." With lizards crawling around me like sassy little black dinosaurs, I had one within a minute. Dr. Perry taught me how to correctly hold a lizard by grasping both legs of one side in the same hand. I named him Bobert. My two minutes of lizard-catching bliss came to an abrupt end as we decided to call it a day.

When the captain and crew saw us heading to the ladder, they picked us up one by one. This time we had to jump from the ladder to the bobbing boat. Again, I almost fell in trying to impersonate Indiana Jones and barely made it onto the boat. I begged the captain to let me take a dip to cool my sunburned body before we headed out and as soon as he agreed, I was out of my field clothes, in my suit, and diving off the side of the boat. I have NEVER swum in such clear water. What I had assumed was only about 15 feet deep was, in fact, more like fifty! It was like swimming in liquid glass.

On the trip home, I thought about what I had seen, a snapshot of a very complex and delicate ecosystem. I wished that we had had more time, a chance to collect at night, to make more observations. I'm sure a whole book could be written about the ecology of Sombrero. Despite the mining operations and the proposed rocket-launching site, Sombrero has hung on. For the moment at least, little black lizards and big Brown Boobies live largely undisturbed by human interlopers — and maybe that's how it should stay.

Acknowledgements

Karim V. D. Hodge, Director, Department of the Environment, Anguilla, facilitated our visit to Sombrero and issued permits for collecting specimens and tissue samples. The Conservation Agency, with a grant from the Falconwood Foundation, chartered the boat that carried us to Sombrero. The staff of Guana Island made arrangements for the charter and supported our efforts in many ways.

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INTRODUCED SPECIES

The Tentacled Snake, *Erpeton tentaculatum* Lacépède 1800 (Homalopsidae), in Florida

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The Tentacled Snake, *Erpeton tentaculatum* Lacépède 1800, is a strictly aquatic species of Asian origin (Winokur 1977), which typically occurs in slow or stagnant bodies of fresh and brackish water (Hahn 1973), often in very turbid lakes, streams, and rice fields (Lovic 2010). This species feeds mostly on fishes, although small amounts of vegetation have also been documented in the diet (Hahn 1973). *Erpeton tentaculatum* possesses a pair of fleshy tentacles on the rostrum, which are likely used as both sensory structures (Winokur 1977) as well as an aid in camouflage (Smith et al. 2002). This species attains an adult length of 50–90 cm total length (Lovic 2010).

On 9 December 2010 at 2023 h, a juvenile (280 mm SVL, 305 mm total length) *Erpeton tentaculatum* was found just outside the property of an animal importer's facility at 6450 Stirling Road, Hollywood, Broward County, Florida (26.04591ºN, 80.21976ºW, WGS84 datum). This snake was found under a piece of artificial human debris directly adjacent to a source of water. The individual appeared dead, likely because of the cold (13 ºC) evening, but revived after being warmed. The snake was deposited in the Florida Museum of Natural History, University of Florida (UF 163086). Species identification was confirmed by Gregory Watkins-Colwell, Yale Peabody Museum.

The introduction pathway for *Erpeton tentaculatum* in Florida is the pet trade. The adjacent areas surrounding the active facility are well known for unusual non-indigenous species and frequently searched for their illegally released or escaped animals. This snake likely had escaped from an enclosure at the importer's facility or was intentionally released, and represents the first known voucher for this family and species in Florida. Further searches by the authors and colleagues have failed to turn up any more individuals of *Erpeton tentaculatum*, and a breeding population is not suspected, nor likely due to insufficient habitat in the general area.

Tentacled Snake (*Erpeton tentaculatum*) (UF 163086), collected on 9 December 2010 in Hollywood, Broward County, Florida.

Acknowledgments

We truly thank Javier Borrero (Aycock Veterinary Clinic) for permission to collect animals on private property directly adjacent to the animal importer's facility; Gregory Watkins-Colwell (Peabody Museum of Natural History) for species confirmation; and Gad Perry, Robert Powell, Tom Chesnes, and an anonymous reviewer for providing helpful comments on this research note.

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Cuban Brown Anoles (*Anolis sagrei*) in Saint Lucia

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Photographs by Nathan A. Wood (Durrell Wildlife Conservation Trust)

Cuban Brown Anoles (*Anolis sagrei*) are native to the Bahama Islands (Cay Sal, Conception, Crooked, Acklins, Grand Bahama, Little Bahama, Rum Cay, and San Salvador island banks), Cuba and associated cays, Isla de La Juventud, and Little Cayman, including most satellites and cays with even rudimentary vegetation. The species also has become established in Jamaica, either naturally or through human mediation. More recently introduced populations are known in Grand Cayman, Swan Island, Sint Maarten, Grenada, Saint Vincent, the Grenadines (Canouan), Barbados, the Atlantic Coast of México as far as Belize, the Islas de la Bahía (off Honduras), Aruba, Hawaii (Oahu and Coconut Island, Kauai), Taiwan, the southeastern United States, and California (Orange County; Henderson and Powell 2009 and references therein, Fläschendräger 2010).

Male (A and B) and female (C) Cuban Brown Anoles (*Anolis sagrei*) from La Toc on St. Lucia. Photographic vouchers have been deposited in the Milwaukee Public Museum (MPM P-753). The identity of these lizards and the individual photographed in 2003 was confirmed from photographs by Robert W. Henderson (MPM).

At least some introduced populations originated in the southeastern United States.

An individual of this species was first photographed and recorded by one of us (CAC) on 8 June 2003 at his residential property at La Toc, just west of Saint Lucia's capitol, Castries (photographic voucher Milwaukee Public Museum MPM P-752). The single male was found in a stockpile of cable television wire on old timbers in contact with the ground. The species is not known to have been seen again until reports were received on 5 December 2010 from a second residential property at La Toc, approximately 300 m northwest of the first sighting at 14°0'35"N, 61°0'13.5"W. This site is approximately 1.3 km southwest of Saint Lucia's main sea cargo port, Port Castries. Ten *A. sagrei* were captured and photographed at this second site; three of these photographs have been deposited as museum vouchers (see figure). At this second site, individuals were found on and near construction materials (primarily lumber) and on fence posts around a small overgrown garden plot. Endemic *A. luciae* and introduced *A. wattsi* were observed within a few meters of *A. sagrei*, and introduced *A. extremus* was observed within 100 m. As *A. luciae* can attain a larger adult size than *A. sagrei* (Henderson and Powell 2009), negative effects on Saint Lucia's native anole might be minimal, as suggested for effects of *A. sagrei* on endemic *A. aeneus* and *A. richardii* on Grenada (Greene et al. 2002).

Whether the newly established population remains largely restricted to severely altered habitats, as on Grenada (Greene et al. 2002, Germano et al. 2003), Saint Vincent (Henderson and Powell 2005, Treglia 2006, Treglia et al. 2008, Eales and Thorpe 2010), and Sint Maarten (Fläschendräger 2010) remains to be determined. The origin of the population on Saint Lucia is unknown, although the location for our sightings suggests that the introduction pathway was likely cargo, probably lumber, from the southern United States, again as suggested for the introduction of this species to Grenada (Greene et al. 2002).

Acknowledgements

The location at which vouchers were taken was first brought to our attention by Gerard and Niall Bergasse, who kindly gave us access to the site and helped us catch the lizards, as did Barbara Schaeffer, Benji Barca, Mike Ball, Nate Woods, Nick Condie, and Twyla Holland. MNM is funded by the Balcombe Trust and works in Saint Lucia alongside Durrell's program counterparts in the Saint Lucia Forestry Department (Ministry of Agriculture, Lands, Forestry & Fisheries).

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A Failed (?) Introduction of Lizards and Frogs on St. Vincent

Amos Glasgow

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In late October 2010, quarantine officers working in Layou, St. Vincent, discovered two Cuban Brown Anoles (*Anolis sagrei*) and three Greenhouse Frogs (*Eleutherodactylus planirostris*) in a container of ornamental plants shipped by Plantation Spice Growers in Goulds, Miami-Dade County, Florida. Photographic vouchers for *A. sagrei* and specimens of *E. planirostris* are deposited in the Milwaukee Public Museum (MPM-P754 and MPM 33993–5, respectively). Robert Powell confirmed the identity of the anoles and Kenneth L. Krysko that of the frogs from photographs. Robert W. Henderson confirmed the identification of the frogs after examining specimens.

Both species are native to Cuba, most Bahamian islands, and at least some of the Cayman Islands. Both have been present in Florida, the origin of this and presumably most other introductions of both species, for over a century (Meshaka et al. 2004). *Anolis sagrei* has been documented from a number of locations outside its natural distribution and is already established on St. Vincent (Henderson and Powell 2005, Treglia et al. 2008, Eales and Thorpe 2010) and elsewhere in the region (Powell et al. 2011). Although effects on native anoles have to date been limited (Treglia et al. 2008), largely because of the relatively restricted distribution of *A. sagrei* on St. Vincent, that species has expanded its range to the point where eradication is likely to be impossible. However, augmenting established populations or introducing lizards to new sites (such as Layou) should be avoided in order to prevent more widespread competitive interactions with native congeners.

Introduced populations of *Eleutherodactylus planirostris* are established on Great Inagua Island (Bahamas), Jamaica, and the Caicos Islands, and have been introduced to Grenada and possibly Guadeloupe, but are not known to be established there (Powell et al. 2011). If *E. planirostis* became established, it would probably interact most intensely with *E. johnstonei*, which is ubiquitous at low elevations on St. Vincent, phenomenally abundant in urban areas and disturbed habitats, and is itself an introduced species (e.g., Mallery et al. 2007, Powell and Henderson 2007). Although *E. planirostris* is generally considered to be more terrestrial than *E. johnstonei*, the latter is quite abundant in terrestrial situations (under rocks and debris in ditches and on the ground) on St. Vincent (Mallery et al. 2007), and frogs in at least some populations of *E. planirostris* are routinely found in arboreal situations (e.g., bromeliads; Henderson and Powell

ALEJANDRO J. SÁNCHEZ MUÑOZ

This male Cuban Brown Anole (*Anolis sagrei*) is part of an established population in the Montrose neighborhood in Kingstown, St. Vincent and the Grenadines. Individuals shipped into Layou could have founded an additional colony if not for the actions of the quarantine officers.

AMOS GLASGOW

These Greenhouse Frogs (*Eleutherodactylus planirostris*) were discovered in a shipment of ornamental plants from Florida.

2009). However, in its native range *E. planirostris* reaches elevations that, if exploited on St. Vincent, could result in contact with endemic *Pristimantis shrevei*, which is listed as Endangered on the IUCN Red List (Hedges and Powell 2004) and already is threatened by competition with *E. johnstonei* and ongoing declines in habitat quality and extent.

Individuals of either species are unlikely to have escaped detection, but the organization that received the plants (Nature Care SVG) has been instructed by quarantine officers to monitor them closely while still on-site and after any sales and relocations.

Acknowledgements

The quarantine officers at Layou are to be commended for their diligence in discovering these invasive animals and for bringing them to the attention of the Forestry Department. I thank Robert W. Henderson, Kenneth L. Krysko, and Robert Powell for identifying specimens.

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The Pacific Coast Giant Musk Turtle, *Staurotypus salvinii* Gray 1864 (Kinosternidae), a New Non-indigenous Species in Florida

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Photographs by the senior author.

The Pacific Coast Giant Musk Turtle, *Staurotypus salvinii* Gray 1864, is indigenous to the Pacific lowlands of Oaxaca and Chiapas, Mexico, ranging eastward into El Salvador and Guatemala (Ernst and Barbour 1989). This species feeds on fishes, invertebrates, and amphibians, and lives in slow-moving, soft bottom lakes, rivers, and other waterways with aquatic vegetation (Ernst and Barbour 1989).

On 2 October 2010 at 1400 h, an adult (270 mm carapace length [CL]) female *Staurotypus salvinii* (Fig. 1; photographic voucher UF 160342) was collected on the property of Zoo Miami, Miami-Dade County, Florida, along the perimeter fence of a hoof-stock exhibit adjacent to a 0.85-km-long man-made lake (25.60276°N, 80.40123°W, WGS84 datum). This *S. salvinii* was placed in the zoo's quarantine facility for a future exhibit, where it was kept in a 300-gallon enclosure. On 26 October 2010, the animal was radiographed because of unusual behavior and discovered to contain two calcified eggs (Fig. 2). On 15 November 2010, this *S. salvinii* oviposited the two eggs in substrate of sand and leaf litter in the enclosure. These eggs (10.1 g, 39.5 x 20.8 mm; 9.9 g, 39.5 x 19.7 mm, respectively) were removed and placed on vermiculite substrate and incubated within a GQF 1550 Hatcher Incubator (Savannah, Georgia) at 28.6 °C with a humidity of approximately 80%. On 2 December 2010, the two eggs appeared to have failed to develop and were discarded.

On 1 November 2010 at 1210 h, a juvenile (107 mm CL) female *Staurotypus salvinii* (Fig. 3; photographic voucher UF 162276) was collected crossing a zoo service road between exhibits (25.61079°N, 80.40068°W), 0.9 km north of the first individual. The nearest water source to this location is a 0.13-km-long man-made lake, which is not connected to the larger, 0.85-km lake where the first individual was found. This *S. salvinii* was also placed in the zoo's quarantine facility for a future exhibit, where it was kept in a separate enclosure.

Zoo Miami contains approximately 300 ha of pine rockland, approximately 133 ha of which are developed for the institution. Although much

Fig. 1. Adult female (UF 160342) Giant Musk Turtle, *Staurotypus salvinii*, from Miami, Miami-Dade County, Florida.

Fig. 2. Radiograph of female (UF 160342) Giant Musk Turtle, *Staurotypus salvinii*, from Miami, Miami-Dade County, Florida.

Fig. 3. Juvenile female (UF 162276) Giant Musk Turtle, *Staurotypus salvinii*, from Miami, Miami-Dade County, Florida.

of eastern Miami-Dade County consists of urban development, properties directly adjacent to the zoo comprise large tracts of mostly undeveloped pine rockland. None of these pine rockland areas are residential, and for security the zoo is bordered by a 2.5-m-tall chain-link fence and concrete perimeter moat. *Staurotypus salvinii* has never been kept as part of the zoo's collection, but is available through the pet trade, which is likely the invasion pathway. Although this species was probably intentionally released on the grounds by a zoo visitor, we acknowledge that it also could have been released along perimeter properties because of gaps under gates and other potentially compromised areas. Like in other Miami-Dade County parks (e.g., see Krysko et al. 2010), numerous non-indigenous amphibian and reptilian species frequently are found on or near zoo grounds; these were likely released by zoo visitors and/or previous owners who no longer want to care for their animals. The presence of multiple *S. salvinii*, including a female with eggs and a juvenile found at different sites on zoo grounds, suggests likely reproduction and establishment of this species there. However, before making this claim we believe evidence of reproduction in the wild is necessary. This is the first known documented introduction of this species in Florida.

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CONSERVATION RESEARCH REPORTS

Conserving Hellbenders

Hellbenders (*Cryptobranchus alleganiensis*) are obligate aquatic salamanders that are in decline due to habitat loss and disease. Two subspecies have been described based on morphological characteristics: *C. a. alleganiensis* (eastern subspecies) and *C. a. bishopi* (Ozark Hellbender). Current conservation strategies include captive propagation for restorative releases even though information regarding the current levels of genetic variability and structure within populations is not sufficient to effectively plan for conservation of the genetic diversity of the species. To investigate patterns of population structure in the Hellbender, **Crowhurst et al.** (2011. *Conservation Genetics*, DOI: 10.1007/s10592-010-0170-0, published online 28 December 2010) genotyped 276 Hellbenders from eight Missouri River drainages, representing both subspecies. Their results showed low levels of within-drainage diversity but strong population structure among rivers, and three distinct genetic clusters. *F ST* values ranged from 0.00 to 0.61 and averaged 0.40. The results confirmed previous reports that *C. a. bishopi* and *C. a. alleganiensis* are genetically distinct, but also revealed an equidistant relationship between two groups within *C. a. bishopi* and all populations of *C. a. alleganiensis*. Current subspecies delineations do not accurately incorporate genetic structure, and for conservation purposes, these three groups should be considered evolutionarily significant units.

ADAM L. CRANE

Eastern Hellbenders (*Cryptobranchus alleganiensis alleganiensis*) are genetically distinct from two groups within what has been traditionally considered the Ozark Hellbender (*C. a. bishopi*). All three represent evolutionarily significant units that should be addressed separately by efforts to conserve them.

NATURAL HISTORY RESEARCH REPORTS

Hurricanes and Amphibian Communities in Coastal Wetlands

Isolated wetlands in the southeastern United States are dynamic habitats subject to fluctuating environmental conditions. Wetlands located near marine environments are subject to alterations in water chemistry due to storm surges during hurricanes. **Gunzburger et al.** (2010. *Wetlands Ecological Management* 18:651–663) evaluated the effect of storm surge overwash on wetland amphibian communities. They sampled 32 wetlands in northwestern Florida over a 45-month period to assess amphibian species richness and water chemistry. During this study, seven wetlands were overwashed by storm surge from Hurricane Dennis, which made landfall on 10 July 2005 in the Florida panhandle. Specific conductance across all wetlands was low pre-storm (<100 µS/cm), but increased post-storm at the overwashed wetlands (mean = 7,613 µS/cm). Increased specific conductance was strongly correlated with increases in chloride concentrations. Amphibian species richness showed no correlation with specific conductance. One month post-storm the authors observed slightly fewer species in overwashed compared with non-overwashed wetlands, but this trend did not continue in 2006. More species were detected across all wetlands pre-storm, but no difference was detected between overwashed and non-overwashed wetlands when considering all amphibian species or adult anurans and larval anurans separately. Amphibian species richness did not appear to be correlated with pH or the presence of fish, although the amphibian community composition differed between wetlands with and without fish. Results suggest that amphibian communities in wetlands in the southeastern United States adjacent to marine habitats are resistant to the effects of storm surge overwash.

SUZANNE L. COLLINS, CNAH

Newly employed imaging techniques revealed circumdiel activity and long periods of surface activity in Crawfish Frogs (*Lithobates areolatus*). Whether these activity patterns are unique to Crawfish Frogs is at this time unknown.

Site Fidelity and Extended Activity in Crawfish Frogs

Crawfish Frogs (*Lithobates areolatus*) base their nonbreeding activities in and around the entrances of crayfish burrows. This site preference allows monitoring of individuals using still and video imaging techniques. **Hoffman et al.** (2010. *BioScience* 60:829–834) used three camera types offering different continuities, scales, and resolutions of data to observe activity patterns and nonbreeding behaviors. The authors observed two behaviors not previously reported for amphibians: (1) Circumdiel activity patterns, and (2) long periods (days) of surface activity. Although these behavioral findings are at this time specific to Crawfish Frogs, they might not be unusual activity patterns for other frogs. The use of imaging techniques that take advantage of this species' dependence on burrows and use of burrow entrances facilitated the observation of these patterns for the first time.

SUZANNE L. COLLINS, CNAH

Species not detected post-storm from overwashed wetlands but present in non-overwashed wetlands were *Hyla squirella*, *Pseudacris ornata* (top), *Lithobates* (*Rana*) *catesbeianus*, *Lithobates* (*Rana*) *clamitans* (middle), and *Pseudobranchus striatus* (bottom). Two of these species, *L. clamitans* and *L. catesbeianus*, were also not detected at the overwashed wetlands prior to the storm.

NEWSBRIEFS

Iguana Conservation in Hispaniola and Fiji

The endemic and Critically Endangered Ricord's Iguana (*Cyclura ricordii*), is restricted to south-central Hispaniola, where four disjunct subpopulations remain in an area less than 100 km². Three subpopulations occur within the Jaragua-Bahoruco-Enriquillo Biosphere Reserve in the Dominican Republic (DR). The fourth, the smallest, and most threatened subpopulation is found in southeastern Haiti.

Conservation activities in the DR focus on habitat monitoring and regular patrolling by members of local support groups to prevent disturbances. This integrative, low-cost program is effective, raises awareness, and serves as a model for other endangered species programs in the DR. In September, with funding from an anonymous donor, the International Iguana Foundation (IIF) and Grupo Jaragua purchased 20 hectares in the DR encompassing a critically important nesting area for Ricord's Iguanas called Fonda de la Tierra near Pedernales. Over 140 hatched nests were documented in this area earlier this year. In Anse-a-Pitres, Haiti, where the most fragile subpopulation of Ricord's Iguana exists, the IIF and Grupo Jaragua recently conducted a workshop for local authorities with a proposal to create a Municipally Protected Habitat. If successful, this protected area would be the first of its kind in Haiti. The IIF, USFWS, MacArthur Foundation, Disney, and Sociedad Española de Ornitología support work on Ricord's Iguana.

JOHN F. BINNS

PETER HARLOW

The smallest and most threatened population of Ricord's Iguana (*Cyclura ricordii*; top) is in southeastern Haiti. The discovery of Fijian Banded Iguanas (*Brachylophus bulabula*; bottom) on two government-owned islands might serve to facilitate establishment of a new national park.

In Fiji, two significant findings emerged from fieldwork conducted over the past year by the National Trust of Fiji, University of the South Pacific, Fiji Department of Environment, NatureFiji-MareqetiViti, Taronga Zoo, and the US Geological Survey. The first finding was the discovery of sizeable populations of the newly described Fijian Banded Iguana (*Brachylophus bulabula*) on two government-owned islands, Mokogai and Makodrago. These populations will hopefully serve as the focus of an assessment for a potential new national park within Fiji.

The second finding was confirmation that Green Iguanas (*Iguana iguana*), illegally introduced to Fiji earlier this century, now occur on at least four islands with documented breeding on two islands. Green Iguanas are highly invasive, and juveniles are very similar in color and shape to the threatened endemic iguanas of Fiji, a similarity expected to hamper control efforts. Partial funding for fieldwork in Fiji came from CEPF and the IIF.

Glenn Gerber and Miguel García
Co-Chairs, Iguana Specialist Group
With contributions from Ernst Rupp, Masani Accimé, and Robert Fisher
IUCN *Species* 52:21–22

Bringing Down the Serpent King

A broken lock on a suitcase moving through Kuala Lumpur International Airport this summer led to the discovery of nearly 100 baby Boa Constrictors, two vipers, and a South American turtle. This was a fairly modest cache for a wildlife smuggler, but the man who claimed the suitcase was no ordinary criminal. He was Anson Wong Keng Liang, the world's most notorious wildlife trafficker — and, instead of a slap on the wrist, which he might reasonably have expected, Wong was about to receive a surprising punishment.

From the tiny Malaysian island of Penang, in a storefront no larger than your average nail salon, Wong commanded one of the world's largest wildlife trafficking syndicates. Much of the work of Wong's company, Sungai Rusa Wildlife, was above-board. He legally wholesaled tens of thousands of wild reptiles annually, making him the likely source for many of the snakes, lizards, turtles, and frogs on sale in American pet stores. However, using a private zoo as a cover, he also offered an astounding array of contraband, including Snow Leopard pelts, panda skins, rhino horns, rare birds, and Komodo Dragons. He smuggled critically endangered wildlife from Australia, China, Madagascar, New Zealand, South America, and elsewhere to markets largely in Europe, Japan, and the United States.

Wong's long career beyond the reach of the law offers a window on the $10–20 billion-a-year illegal wildlife trade and our broken system to combat it. Underfunded law enforcement, government corruption, controversy-shy NGOs, and a feeble international legal framework have yielded few inroads against wildlife syndicates or kingpins like Anson Wong. Wong's arrest and his sentencing in November 2010 provide a lesson on how to change that.

Wong got into the business in the early 1980s, selling exotic animals to zoos and dealers around the world. Changes in international and Malaysian law eventually led him to focus on reptiles, which he believed were not as protected as other species. Wong's techniques mirrored those of narcotics and other traffickers. He paid mules to carry Komodo Dragons hidden inside suitcases, and hid endangered Malagasy Tortoises at the bottom of legal wildlife shipments. Purchasing vacation packages as cover, he sent men out to poach rare wildlife from breeding facilities in New Zealand. The most important technique Wong and other large-scale smugglers employ, however, is far less exotic than all that. Instead, it has to do with paperwork.

The primary treaty governing international wildlife trade is the U.N. Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), which classifies wildlife into three groups: Animals listed in Appendix I, such as tigers and gorillas, are so close to disappearing that they are banned from international commercial trade; Appendix II animals may be traded under a permit system; and Appendix III animals are protected by a country with a request that others honor the protection. Smugglers scan the globe for countries with weak laws or corrupt law enforcement officials tasked with stamping their animals' documentation, paper that is as much in demand as the animals themselves. Such countries become wildlife laundering pass-through points — animals come in illegally and leave "legally."

Few places launder as much illegal wildlife as Penang. This was largely the work of Wong: "I can get anything here from anywhere," he boasted to an American undercover agent in March 1997. "Nothing can be done to me. I could sell a panda — and, nothing. As long as I'm here, I'm safe." The key, he explained, was paying off government officials.

Wong's activities finally landed him on the radar of international law enforcement agencies in the early 1990s, when Special Operations, the elite undercover unit of the U.S. Fish and Wildlife Service (USFWS), made him the target of an investigation called Operation Chameleon. Agents set up a reptile importing company outside San Francisco and a retail operation in

Reno, Nevada, and began doing business with Wong. Before long, they discovered Wong not only smuggled rare and endangered reptiles, but also critically endangered birds and mammals. His reach was global.

To arrest Wong, agents needed a ruse to lure him out of Malaysia. A lucrative international black market in bear bile is fueled by demand as a cure-all in traditional Asian medicine. USFWS Special Agent George Morrison, acting undercover, offered Wong a piece of a bear-bile smuggling operation he claimed to be running, on one condition: The two men had to meet in person. Wong agreed, but because he was already wanted in the United States on smuggling charges, he would only agree to meet in Mexico.

When Wong stepped off a Japan Airlines flight in Mexico City on 18 September 1998, he was met by Morrison, along with Special Assistant U.S. Attorney Robert S. Anderson and a team of Mexican federales, who arrested him. It was the culminating moment of Operation Chameleon, which had grown into one of the longest and most successful undercover operations ever undertaken by the USFWS, and one involving authorities in four countries. Wong fought his extradition from Mexico to the United States for two years, but eventually gave in.

In June 2001, Wong was sentenced in California to 71 months in prison, fined $60,000, and banned from exporting to the United States for three years after his release — but the sentence did not stop him. While he was in prison, his wife ran his wildlife business, including sales to the United States. When he got out in 2003, Wong returned to Malaysia, grew a ponytail, and went back to work.

Wong's U.S. conviction had no discernible impact on his ability to operate in Malaysia. To the contrary, his new plan to build a tiger zoo received funding and land from the Penang government. Misliah Mohamad Basir, the wildlife department official directly responsible for policing Wong, considered him to be a legitimate businessman, and believed the U.S. authorities had framed him.

In the years since the USFWS's revolutionary sting operation took down Wong, the global wildlife kingpin had grown more powerful, while the people who brought him to justice had fallen on hard times. Special Operations failed to make another major case after Wong's; today, its best agents have given up undercover work — and the unit, which never constituted more than a handful of agents, is all but defunct.

Things didn't begin to change until January 2010, when *National Geographic* published a profile of Wong, detailing his government connection and his new plans to exploit tigers. The outcry by both the public and journalists in the Malaysian press was immediate. Malaysian newspapers and television are state-controlled, which makes it difficult for journalists to criticize the government directly — but they are free to disclose foreign reporting about Malaysia. In the course of the past year, the Ministry of Natural Resources and Environment announced a revamp of its wildlife department, promising to rotate senior officers every three years. It stripped the department of key powers and is in the process of transferring Misliah, who is now also under investigation by the Malaysian Anti-Corruption Commission. While international wildlife NGOs were cautious about causing trouble in Malaysia, they have provided invaluable advice to the country's government, including the parliament, which passed the first overhaul of its wildlife law in nearly four decades.


L. LEE GRISMER

Chinese Water Dragons (*Physignathus cocincinus*), such as this juvenile, escaped from the compound of Anson Wong Keng Liang on Penang Island and have become established in nearby waterways where they appear to be displacing some of the native riparian species in the agamid genus *Gonocephalus*.

As a result, when Wong was caught with a suitcase of Boa Constrictors, he didn't get away with it. The Malaysian government revoked his business licenses, shut down his zoo, and seized his entire collection of animals, including his Bengal Tigers. In November, a judge sentenced him to five years in prison, an unprecedented term for a wildlife trafficker in Malaysia.

The effort to catch Wong offers a few important lessons on what it takes to stop a kingpin. Two principles float to the surface. First, where long-term, high-volume international wildlife trafficking exists, one or more government officers are either complicit in the smuggling or so complacent as to be reasonably considered accomplices. As long as a few countries are willing to bend the rules and fudge some paperwork, it doesn't really matter what everyone else does: A single country, even a single wildlife enforcement official, can undermine the entire global "system" to control trafficking.

Second, the public in the kingpin's home country is the best weapon against him. No step to Malaysia's unprecedented legal and administrative reforms this year was more important than the outcry in Malaysia from concerned citizens. Dozens of articles — many of them on Malaysian newspapers' front pages — finally told the story of Operation Chameleon, Wong's Penang operations, and the history of poor management by the country's wildlife department, exposing years of bad policy and official venality.

Exposure is a critical ingredient for change. Law enforcement, NGOs, and others will find their work magnified and lasting once the public becomes aware of it. Full stories need to be told in the media. In the United States, where wildlife trafficking busts are often treated as humorous news items, that means journalists have to realize that criminal syndicates are often behind those people stopped at airports with exotic animals hidden under their clothes.

Of course, no fix is forever. Wildlife smugglers, like any other breed of trafficker, obey the laws of supply and demand. As long as a market for rare and endangered animals exists, someone will supply them. Rising incomes in China, India, and even in southeastern Asia mean more customers for endangered wildlife. In 2009, over 18,000 live animals and more than 267 tons of dead animals and derivative products were seized in law enforcement actions in southeastern Asia alone — and that appetite won't go away just because Wong temporarily did. Whether Malaysia's reforms will take root remains to be seen, as is what will happen upon Wong's release. Still, somewhere in Malaysia or another country someone is all but guaranteed to be willing to look the other way, and aspiring kingpins are eager to take over his business.

Bryan Christy
Adapted from an article.
28 December 2010

Snake Owners See a Furry Bias in Invasive Species Proposal

Many snake lovers have been seething at the American government since early last year, when it sought to ban the importation and interstate transportation of nine species of foreign snakes. The federal Fish and Wildlife Service said the animals, if freed, posed a serious risk to native ecosystems across the southern United States.

When the Fish and Wildlife Service moved to ban trade in the snakes, which include boas and species of anacondas and pythons, it argued that they met the legal criteria for being both injurious and invasive. Invasive species — from Asian carp, which threaten the Great Lakes, to Zebra Mussels, which spread exponentially — are a serious environmental concern, one that is often not dealt with until a species has become firmly established. The Fish and Wildlife Service argues that, in the case of the snakes, they are trying to get ahead of the problem.

It is the first time the government has tried to list animals so widely held as pets. Roughly one million Americans are believed to own snakes of the types listed by the Interior Department, according to the U.S. Association of Reptile Keepers, and 31,000 were imported in 2008, the most recent year for which the government has data. Trade in these species is big business — more than $100 million annually. Those with rare colors can fetch upward of $75,000.

The move to ban the snakes has set off a swell of anger among aggrieved snake owners and breeders, who have the most to lose financially, as well as a smattering of academic herpetologists, zookeepers, and representatives of international conservation groups. When the regulations came up for public review, they flooded the government with objections. At the heart of their arguments is a critique of the emerging science of invasive species risk assessment, and their response has highlighted the challenges that the government faces as it increasingly moves to protect native flora and fauna not just from current invasive species but also from future threats.


SUZANNE L. COLLINS, CNAH

The U.S. Geological Survey estimated that suitable climates for the Burmese Python (*Python bivittatus*) might include the 11 southernmost U.S. states from California to North Carolina. If global warming continued apace, the geological survey added, the snakes might even be at home in New York City by 2100.

The reptile keepers group, which claims 12,000 professional breeders and sellers as members, has filed formal objections with the Interior Department and is threatening a lawsuit based on what it says is the government's poor scientific evidence. Andrew Wyatt, the president of the association, argues that the government is now promoting a native-species-only agenda favored by environmental groups. "This has implications for every animal interest out there, right down to family pets," he said, adding that by such standards, "all amphibians are injurious and cats and dogs can't be far behind."

The battle goes back to 2006, when the South Florida Water Management District petitioned the Fish and Wildlife Service to list the snakes under the Lacey Act, which would make it a crime to transport them into the United States or across state borders. Burmese Pythons — some thought to be dumped by pet owners and some that escaped — were establishing themselves across the Everglades, where they were swallowing up everything from endangered Key Largo Wood Rats to alligators. The population has been expanding northward at roughly three and a half to six miles a year — Indy 500 speeds in reptilian terms.

In recent years, Florida officials had taken significant steps to limit ownership of invasive snakes within the state but still wanted more to be done. What was to protect the Everglades from a snake bought in Georgia and carried across state lines? To ban the snakes under federal law, the government would have to show that they posed a threat to native plants, crops, or animals. With very little science available about how reptiles that come from distant places like subtropical Asia and Africa might fare in America, the U.S. Geological Survey was asked to assess the risk.

The agency looked at many factors, including the damage in the Everglades. It also turned to a computer model to determine what parts of the country might have a hospitable climate for the species. The scientists looked at variables including mean monthly temperatures and rainfall at a wide range of elevations in the native habitats of the animals and matched them to patterns in the United States.

They estimated that suitable climates for the Burmese Python in particular might include the 11 southernmost states from California to North Carolina. If global warming continued apace, the geological survey added, the snakes might even be at home in New York City by 2100. The national news media gave gleeful attention to the prospect of a snake invasion — but soon after, biologists at the City University of New York did their own modeling, using more factors and different ones like precipitation during the wettest periods of the year, and came up with only Florida and southern Texas as possible habitats for the snakes. Independent studies of snakes captured in the Everglades and taken north to Gainesville, Florida, and South Carolina found that most of the animals died when left outside in winter in those regions. These findings were further bolstered when an unusual cold snap in the Everglades last January left a large number of Burmese Pythons dead on canal banks and levees.

The studies have fired up the snake industry, which sees them as proof that the government is pursuing a hostile and unwarranted agenda. One breeder said that the government regulations, which do not prevent breeding and owning but do prevent transportation across state lines, would ruin his business and thousands like it. "The reptile industry would suffer a crushing blow over something that does not make sense," he said.

Dr. Elliott Jacobson, a professor of veterinary medicine at the University of Florida and a specialist in reptiles, also sees the government's science as skewed. He said he suspected that the government was less sympathetic to reptiles than to more cuddly creatures. "The impact of feral cats, for example, on wildlife is much greater than what the Burmese Pythons can do," he said, noting that a cat eats much more than a snake of the same size.

However, Thomas Strickland, assistant secretary for fish and wildlife and parks, said that the government was not going to back down and that it would approve the regulations by next summer. The science is solid, Mr. Strickland said, and the geological survey will soon publish a peer-reviewed answer to its critics. Like other invasive species, snakes are a real and growing problem, he said. "You are not dealing with hamsters here," he said. "I was down in the Everglades, and it took four people to hold a 19-foot Burmese Python. These things wreak havoc."

Leslie Kaufman
New York Times
8 January 2011


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Editors' Remarks

2011 has been designated the Year of the Turtle. The designation recognizes the sad state of many of the world's chelonians and the urgent need to help many species. If you haven't already, we encourage you to check the Focus on Conservation (p. 64) and become involved in some capacity in the 2011 Year-of-the-Turtle efforts to conserve these special creatures.

On a separate but no less urgent issue, the Introduced Species section in this (beginning on p. 52) and recent issues shows that herpetological introductions are ongoing. Documenting them is essential for identifying the mechanisms and outcomes of these events and providing information that regulators can use to address and moderate the problem. The situation is of particular concern on many islands, where endemic species are threatened by competitively superior continental invasives. As Charles Darwin wrote in *The Origin of Species by means of Natural Selection or, The Preservation of Favoured Races in the Struggle for Life* (1872. 6th ed.): "As natural selection acts by competition, it adapts the inhabitants of each country only in relation to the degree of perfection of their associates; so that we need feel no surprise at the inhabitants of any one country, although on the ordinary view supposed to have been specially created and adapted for that country, being beaten and supplanted by the naturalised productions from another land." We encourage the responsible ownership of amphibians and reptiles. If you keep non-native species, please take every precaution yourself, and share with others your concerns over the escape or release of animals to places where they do not belong.

The Editors of *Reptiles & Amphibians*

STATEMENT OF PURPOSE

The International Reptile Conservation Foundation works to conserve reptiles and amphibians and the natural habitats and ecosystems that support them.

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The IRCF encourages contribution of articles, letters to the Editor, news items, and announcements for publication in *REPTILES & AMPHIBIANS.* General articles can deal with any aspect of reptilian or amphibian biology, including conservation, behavior, ecology, physiology, systematics, or husbandry. Submission of photographs to accompany articles is encouraged. Guidelines for submissions and figures are at www.ircf.org/about/submissions. Manuscripts may be submitted via e-mail (send to AJ@IRCF.org). Authors of one page or more of print will receive a free copy of the journal in which their contribution appears, and will receive a PDF file of their article for distribution.

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FOCUS ON CONSERVATION

2011
Year of the Turtle

Turtles are disappearing from the planet faster than any other group of animals. Today, nearly 50% of turtle species are identified as threatened with extinction. However, it's not too late. The United States has more endemic turtle species than anywhere on Earth and is a true turtle biodiversity hotspot. Careful stewardship can preserve the rare species and keep common species common.

The bad news is that humans cause the greatest harm to turtle populations — but the good news is that we have the power to make positive changes toward turtle survival. The greatest threats to turtle populations include: (1) Habitat loss and degradation; (2) over-harvesting of wild turtles for food, traditional medicines, and pets; (3) mortality from roads, agricultural machinery, fishing by-catch, and predators (many of which are non-native); (4) exotic invasive species and diseases; (5) loss of genetically unique populations due to hybridization (often as a consequence of turtles released into areas where they do not occur naturally); and (5) climate change.

Throughout the year, turtle conservation groups in partnership with Partners in Amphibian and Reptile Conservation (PARC) will be raising awareness of the issues surrounding turtles through press releases, newsletters, photo contests, and related events. Citizens, natural resource managers, scientists, and the pet, petfood, and related industries can work together to address issues and to help ensure the long-term survival of turtle species and populations.

Bookmark **www.yearoftheturtle.org** and check it frequently for more information on how you can get involved! The website includes links to 2011 State of the Turtle and USA Turtle Mapping Project, information on submitting a photograph for the Year-of-the-Turtle photo contest, and the 2011 Year of the Turtle video. You can also sign up for monthly newsletters that contain: (1) A downloadable turtle photo calendar for each month (if you enter the photo contest, your photo could be in the calendar!); (2) information about turtle conservation efforts and groups, and how you can help; (3) interviews with turtle experts, and answers to submitted questions; (4) information on how you can help spread the word about turtles; (5) educational materials; (6) turtle art, poetry, and cultural information; and much more! Contact **yearoftheturtle2011@gmail.com** with any questions, or to be a partner in Year of the Turtle.

JOHN WHITE, VIRGINIA HERPETOLOGICAL SOCIETY

The Spotted Turtle (*Clemmys guttata*) is endemic to the eastern United States. It is currently listed as Vulnerable on the IUCN Red List.

DANIEL P. SCANTLEBURY

A male Barahona Limestone Sphaero (*Sphaerodactylus thompsoni*) demonstrates the vertically eliptical pupil it shares with other nocturnal geckos — although very little is known about the activity periods of most species of sphaeros. See the article on p. 12.