IRCF

REPTILES & AMPHIBIANS

CONSERVATION AND NATURAL HISTORY

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TOM TYNING

Science has changed considerably since 1723, when the "black Sattin" color phase was described by Paul Dudley in "An Account of the Rattlesnake" (see the Historical Perspective on p. 122).

ZHI XIAO

Denny's Treefrog (*Rhacophorus dennysi*) appears to be extending its range south of the Tropic of Cancer in eastern Asia (see the article on p. 74).

GERARD VAN BUURT

Male Bonaire Whiptail (*Cnemidophorus ruthveni*) from the Caribbean island of Bonaire. This species was recently elevated from a subspecies of *C. murinus* (see the article on p. 92).

Front Cover: Thomas Wiewandt

Tiger Rattlesnakes (*Crotalus tigris*) increase growth rates and reproductive output in artificially mesic enclaves in desert regions. Consequently, populations separated by very small distances can vary considerably in basic life history traits. The paint on the rattle segments serves to identify individual snakes. See article on p. 84.

Back Cover: Robert Powell

Like all species of West Indian Rock Iguanas, the critically endangered San Salvador Rock Iguana (*Cyclura rileyi*) is primarily herbivorous. This individual was foraging on Green Cay off San Salvador (Bahamas). Look for an article on the reptiles of San Salvador in an upcoming issue of *Reptiles & Amphibians*.

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THOMAS WIEWANDT

Tiger Rattlesnakes (*Crotalus tigris*) tend to give birth in rock outcrops, making it difficult to obtain information on litters. However, diligent radiotracking of gravid females generated considerable data (see the article on p. 84).

CRAIG S. BERG

The senior author recording data on frogs encountered along a transect at Les Avocats. Note the flagging marking 10-m sections of the transect.

The Grenada Frog (*Pristimantis euphronides*): An Endemic Species in Decline and the Combined Effects of Habitat Loss, Competition, and Chytridiomycosis

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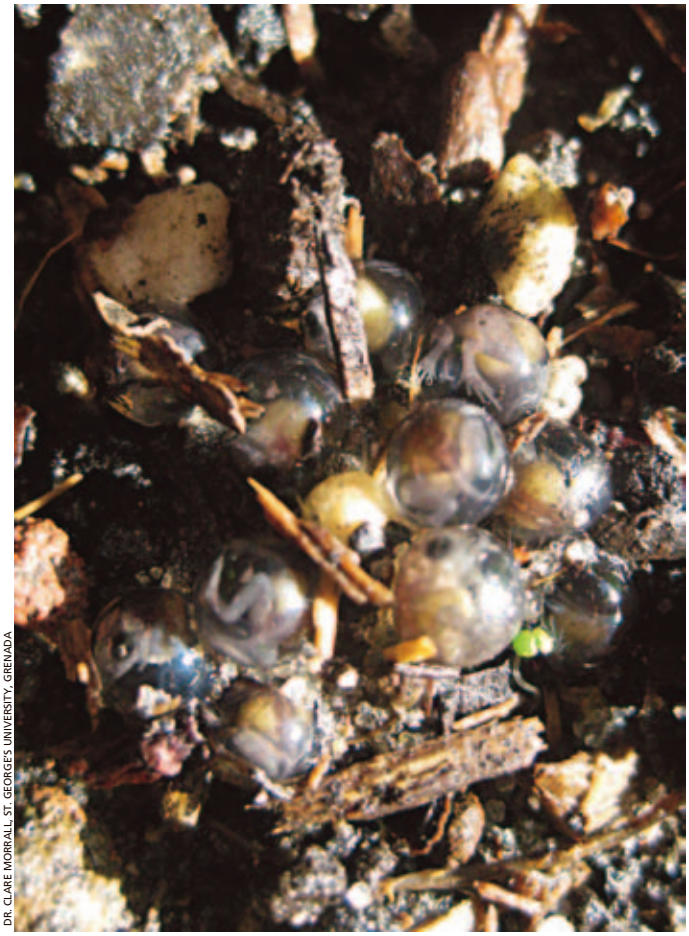
The island of Grenada, West Indies is home to only two endemic terrestrial vertebrates, the Grenada Dove (*Leptotila wellsi*) and the Grenada Frog (*Pristimantis euphronides*). The Grenada Dove is featured on the national emblem and is considered to be a national treasure, while the Grenada Frog is virtually unknown to Grenadians. It is listed as Endangered on the IUCN Red List because of its limited range and competition with Johnstone's Whistling Frog (*Eleutherodactylus johnstonei*). The invasive *E. johnstonei* is practically ubiquitous on the island. Its calls saturate Grenada's nights, and it is the frog with which most Grenadians are familiar.

Grenada is the southernmost island in the Lesser Antilles. It is approximately 311 km^2 and is the largest island on the Grenada Bank. In addition to *P. euphronides* and *E. johnstonei*, it is home to The Windward Island Ditch Frog (*Leptodactylus validus*) and the Cane Toad (*Rhinella marina*), both of which are introduced.

Pristimantis euphronides was formerly considered to be a member of the genus *Eleutherodactylus*, in part because one of the characters that defined that genus was that they are direct developers. Direct developers bypass the tadpole stage and develop directly into froglets inside of the egg. *Pristimantis euphronides* belongs to the recently erected family Strabomantidae (Hedges et al. 2008). Although the Strabomantidae are widely distributed in South and Central America, only two species are endemic to the West Indies, the Grenada Frog and the St. Vincent Frog

BILLIE HARRISON

A Grenada Frog (*Pristimantis euphronides*) on Maidenhair Fern at Cable and Wireless.



DR. CLARE MORRALL, ST. GEORGE'S UNIVERSITY, GRENADA

Direct-developing terrestrial eggs of Johnstone's Whistling Frog (*Eleutherodactylus johnstonei*) — note the froglets in the eggs.

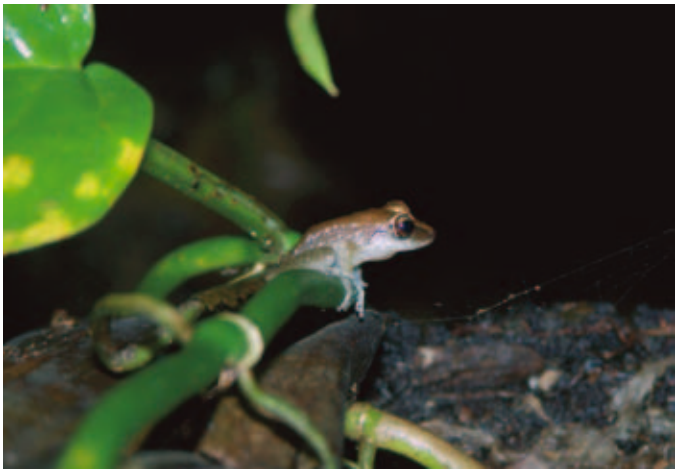
DR. CLARE MORRALL, ST. GEORGE'S UNIVERSITY, GRENADA

Hatchling Johnstone's Whistling Frog (*Eleutherodactylus johnstonei*) — note the fingertips for scale.

(*Pristimantis shrevei*). The Grenada Frog is a relatively small frog; males attain a maximum snout-vent-length (SVL) of 27 mm, with an average of 22.7 mm. Females grow substantially larger, reaching 39.4 mm SVL with an average of 28.3 mm (Kaiser et al. 1994).

Pristimantis euphronides inhabits forests at altitudes over 300 m (Henderson and Berg 2006). Since 2004, we have surveyed five sites for the species and, to date, have never encountered this frog at an elevation below 400 m. However, this may be due to the fact that our sites are accessible by road and therefore are subject to disturbance, both today and in the past. In 1999, Hedges indicated that the distribution of this species was limited to an area of 16 km²; it is likely less than that now. Causes for habitat constriction include changes in land use patterns, competition with invasive *E. johnstonei* (Sander et al. 2003, Schwartz 1967), and the effects of Hurricane Ivan in 2004. The species probably was once more widespread on the island but, during the past 8,000 years, the forested areas of Grenada have shrunk by 70%, mostly due to anthropogenic changes (www.earthtrends.wri.org).

Barbour (1914) described *Eleutherodactylus johnstonei* based upon a specimen collected at St. George's and given to him by Robert S. Johnstone, the Chief Justice of Grenada. The genus *Eleutherodactylus* was until recently included in the family Leptodactylidae, but is now assigned to the family Eleutherodactylidae (Hedges et al. 2008). The geographic origin of this species is unknown, but is believed to be the Leeward Islands (Pregill et al. 1994, Kaiser 1997, Lescure 2000). Barbour (1914) indicated that it arrived on Grenada in 1885 from Barbados. That was likely to have been a noticeable introduction, as its call is loud and dissimilar to any other anuran or insect on the island. Within 50 years, *E. johnstonei* had reached Grand Etang, 10 km inland. Fifty years later, it was widespread across the island, absent only from cool, undisturbed, high-elevation forests. Today *E. johnstonei* can be found in moist and dry coastal areas to high-elevation rainforest or acacia scrub. The species thrives across a broad range of altitudes, temperature regimes, vegetational communities, and levels of human disturbance. These invaders readily occupy houses and exploit cisterns that residents use for water storage during the dry season. Grenadians today con-



TASHA BRNAK

A Grenada Frog (*Pristimantis euphronides*) at Les Avocats in 2010.

CRAIG S. BERG

Johnstone's Whistling Frog (*Eleutherodactylus johnstonei*) generates a piercing call that reaches 91 decibels, roughly the volume of a lawnmower.

sider *E. johnstonei* a nuisance, largely attributable to its shrill call (other frog species on the island have less raucous calls). Its call is two-tone, one note at 2,000 Hz and another ascending note from 2,000–3,500 Hz (see fig. 1 in Watkins et al. 1970). The call reaches 91 decibels, roughly the volume of a lawnmower (Tárano and Fuenmayor 2009) and individuals can emit as many as 60 calls per minute (Kaiser and Hardy 1994).

One of the most widely distributed amphibians in the world, *Eleutherodactylus johnstonei* is third only to the Bullfrog (*Lithobates catesbeianus*) and the Cane Toad (*Rhinella marina*; Kaiser 1997; Kraus 2009; amphibiaweb.org) in size of total range. It has successfully invaded many different habitat types in the greater Caribbean (where it is known from 28 islands or island groups; Powell et al. 2011) and on mainland Central and South America. Before the 1970s, these frogs were found principally on islands that were British protectorates. The dissolution of the protectorates opened new trade routes between islands and greatly accelerated the frog's dispersal. Shipments of plants are frequently cited as sources of inadvertent introductions (e.g., Kraus et al. 1999, Hodge et al. 2003, Powell et al. 2011).

Eleutherodactylus johnstonei possesses many traits that might provide it with a competitive advantage over *P. euphronides* in disturbed habitats, whether anthropogenic or natural. Kaiser et al. (1994) hypothesized that competition with Johnstone's Whistling Frog was causing a range reduction of the Grenada Frog. In 2004, surveys were initiated to determine if, indeed, *P. euphronides* was in decline and, if so, the proximate causes of the decline. An additional goal was an attempt to detect any drastic decreases in frog populations that might be associated with the arrival of amphibian chytrid fungus on Grenada.

Materials and Methods

Since February 2004, we have been monitoring established survey sites by walking timed transects. We conduct 30-minute searches along 100-m transects. Each 100-m transect is divided into ten 10-m sections to facilitate a near constant survey pace. All surfaces within 2 m of the transect are scanned for frogs. We record species, age class, sex (if known), perch type and height, and section number within the transect. This allows us to compare frog numbers and species ratios at different sites and make same-site comparisons on a year-to-year basis. Microhabitat parameters are monitored by data-loggers that record soil surface temperature (Tidbit v2; www.onsetcomp.com), and air temperature/relative humidity (HOBO Pro v2; www.onsetcomp.com) at our survey sites. To date, five sites have been surveyed following this protocol, but only three sites (Grand Etang, Les Avocats, and Cable and Wireless) are currently being monitored. Each site was selected because it represented a distinct habitat type.

CRAIG S. BERG

Habitat at Grand Etang immediately after Hurricane Ivan in 2004 (top) and today (February 2011).

JOHN S. PARMERLEE, JR.

Map of Grenada indicating localities mentioned in the text. Contour lines are at 120 m, 365 m, and 610 m.

Grand Etang National Park (St. Andrew Parish; 525 m).—Grand Etang is the type locality for the Grenada Frog. Hurricane Ivan devastated the forest along the mountain crest. Trees were snapped off at their trunks or completely uprooted. What was once a closed-canopy forest with many trees and tree ferns (*Cyathea* sp.) attaining heights of 30 m (Beard 1949) became an open and sun-drenched landscape. Ferns and tree ferns are to this day a major component of the flora, but Razor and Saber grasses (*Scleria* sp.), which were rare prior to Hurricane Ivan, now cover substantial portions of the forest floor. This site is bathed, almost nightly, by a mist formed from condensation as warm, moist tradewinds emanating from the Atlantic Ocean move up slope into the cool night air of Grenada's mountain ranges. Rain can be expected almost nightly, especially during the wet season.

Cable and Wireless Station (St. Andrew Parish; 705 m).—Cable and Wireless was considered to be a Grenada Frog bastion and one of a few places on the island where the topography is too treacherous to be cleared for agriculture (Kaiser and Henderson 1994, Sander et al. 2003, Henderson

BILLIE HARRISON

The moist upland forests at the Cable and Wireless station, one of a few places on the island where the topography is too treacherous to be cleared for agriculture.

and Berg 2006). Prior to Hurricane Ivan, the flora was composed of broadleaf trees and shrubs, tree ferns (*Cyathea* sp.), and other ferns. Today the vegetation is predominantly Saber Grass (*Scleria* sp.) and ferns. Because the elevation of this site is 175 m higher than Grand Etang, the air is cooler and rains or mists are nightly events.

Les Avocats Water Works (St. Davids Parish; 400 m).—Although Les Avocats is part of Grand Etang National Park, it is located between two mountain ridges that protected it from the full onslaught of Hurricane Ivan. Consequently, the forest at Les Avocats has retained most of its canopy. The ridges also hinder the development of the mists that blanket the other two sites. Tree ferns (*Cyathea* sp.) are rare; Bamboo (*Bambusa vulgaris*) and *Heliconia* sp. are common. Razor and Saber grasses (*Scleria* sp.) are absent.

CRAIG S. BERG

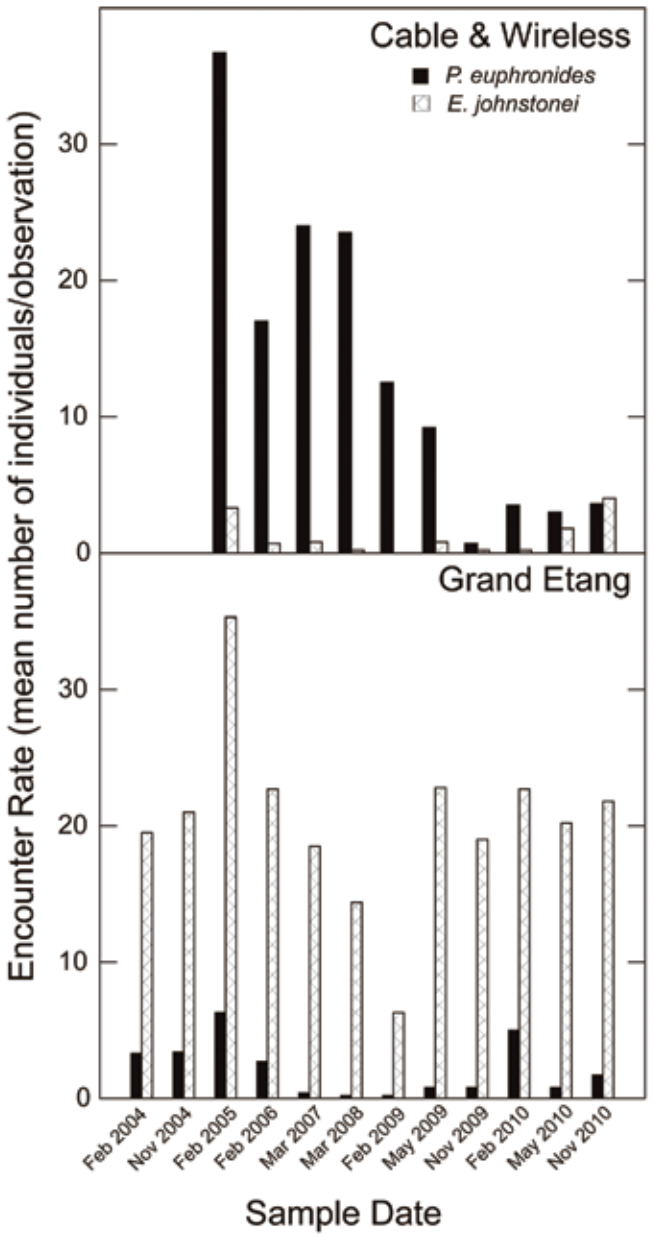
The senior author recording data on a Grenada Frog (*Pristimantis euphronides*) at Les Avocats.

Results

Results of our surveys show a decline in populations of *Pristimantis euphronides* and *Eleutherodactylus johnstonei*. The decline has been relatively consistent, occurring during both wet years and those of extreme drought. Amphibian populations are known to vacillate with environmental conditions, prey availability, and breeding-site availability. However, in hot and dry conditions, populations of *P. euphronides* declined whereas those of *E. johnstonei* maintained relatively stable numbers. The most remarkable decline was at Cable and Wireless, where environmental conditions are the most stable. This trend fits the pattern of declines attributable to pathogens.

We began to suspect that the deadly fungus *Batrachochytrium dendrobatidis* was contributing to declines in *P. euphronides*. In May 2009, we swabbed frogs, taking 80 samples from three species (Johnstone's Whistling Frog, Grenada Frog, Windward Island Ditch Frog) at four locations. Chytrid was found at all four sites and in all three species. It likely poses the most severe and imminent threat to the Grenada Frog, which is found only at high elevations where temperature and moisture regimes are ideal for the chytrid fungus.

Evidence of frog declines first emerged at Grand Etang in 2007, followed by a decline at Les Avocats in 2008 and at Cable and Wireless in 2009. This pattern would be expected of a pathogen arriving at a Grenadian



MIKE PAUERS

Graph showing encounter rates of Grenada Frogs (*Pristimantis euphronides*) and Johnstone's Whistling Frogs (*Eleutherodactylus johnstonei*) at two localities on Grenada between 2004 and 2010.

port, as the road that runs past our survey site at Grand Etang is the main road connecting Grenada's two major ports, St. George's and Grenville. This same road also brings busloads of tourists from cruise ships to view Grand Etang and walk along its forest trails. So, chytrid arriving via inter-island commerce (horticultural specimens, hitch-hiking frogs, construction materials, etc.) or in the mud-caked boots of eco-tourists would quickly be transported to and through Grand Etang. The frogs at Grand Etang and Les Avocats likely belong to the same meta-population and, if that is so, any pathogen infecting animals at Grand Etang would later appear at Les Avocats. Eventually, chytrid would make its way to Cable and Wireless.

We continue to collect samples from populations across the island in an effort to map the range of this deadly amphibian fungus. Most recently, we collected samples from the forest reserve at Mt. Stanhope. With combined stressors such as drought, habitat loss, reduced canopy cover, and competition with *E. johnstonei*, *P. euphronides* might not be able to withstand the additional pressure imposed by exposure to the chytrid fungus.

Discussion

Several traits would likely provide *Eleutherodactylus johnstonei* with a competitive advantage over *Pristimantis euphronides* in disturbed habitats. Johnstone's Whistling Frogs have exhibited tolerance of extreme temperature variation and desiccation. In a study of *Eleutherodactylus* on Jamaica, the introduced Johnstone's Whistling Frogs survived at temperatures to 40 °C and a 40% loss of their initial weight in water; by comparison, Jamaican endemics did not show comparable tolerances (Pough et al. 1977).

Direct developers do not rely on pools of water for ovopositioning sites, but rather sites that will remain moist throughout the developmental period. In the case of *E. johnstonei*, the female lays clutches of 5–30 eggs, which are typically attended by the male until hatching. During dry periods, the male grasps and broods the clutch. This action limits desiccation throughout development. Hatching occurs after 14–21 days. Because the male usually remains with the egg mass, females are free to feed and build the metabolic reserves necessary to produce another clutch of eggs. Clutches of *P. euphronides* are protected by the female until hatching. Because female *P. euphronides* have not been observed to feed (CSB, pers. obs.) while brooding, they need to build reserves necessary for producing another clutch. This difference in parental care could give *E. johnstonei* a reproductive advantage over *P. euphronides*.

Both species retreat beneath leaf litter and crevices in the substrate to avoid desiccation. These sites are used as diurnal retreats and during breeding and ovipositing. Eleutherodactylids vigorously protect nesting sites against other frogs (e.g., Townsend 1984, Bourne 1997). Both species would compete for appropriate ovopositioning sites (Lips and Donnelly 2005), and retreat availability is a limiting factor in eleutherodactylid population size (Stewart and Pough 1983).

In captivity, *P. euphronides* digs holes into the substrate whereas *E. johnstonei* does not (CSB, pers obs.). The soil at Les Avocats and Grand Etang consists of heavy clay, which is practically impenetrable. During the dry season, frogs must compete for available cavities, which are restricted to those that are formed naturally. The substrate at Cable and Wireless is composed of a thick layer of moss-covered decaying vegetation that enables *P. euphronides* to burrow. Because *P. euphronides* is able to dig into the substrate at Cable and Wireless, it does not need to compete with *E. johnstonei* for diurnal retreats and/or ovopositioning sites. At Les Avocats and Grand Etang, the numbers of *E. johnstonei* greatly exceed the numbers of *P. euphronides* and thus would likely swamp available ovoposition sites.

Eleutherodactylus johnstonei is known to share cover objects (Ovaska 1991) and may share them with *P. euphronides*. *Pristimantis euphronides* and *E. johnstonei* have been observed perching on the same plants and even on the same leaf (e.g., Germano et al. 2003). This close proximity could

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A Johnstone's Whistling Frog (*Eleutherodactylus johnstonei*) in a natural crevice at Les Avocats.

CRAIG PELKE

A female Grenada Frog (*Pristimantis euphronides*) attending a clutch of eggs.

indicate that the two species do not recognize each other as direct competitors for perch sites or prey. Close proximity is, however, likely to aid the transmission of chytrid.

Implications for Grenada and Other Islands

Insular endemics such as the Grenada Frog often rely on undisturbed forested areas. As of 2000, Grenada had lost 70% of its forests to agriculture or development. Managing for endemics may no longer be practical or possible without also protecting appropriate habitat. Assurance colonies can be maintained in *ex-situ* institutions, but the number of amphibian species requiring such efforts greatly exceeds the number of institutions that have the resources necessary to maintain bio-secure holding facilities. In order to ensure that threatened fauna survive in perpetuity, collaborative efforts on behalf of all stakeholders are necessary. Conservation action plans need to be developed to enable Caribbean forestry and wildlife departments to sustainably manage endangered ecosystems. Adequate training in amphibian biology and conservation initiatives is needed for local forestry/wildlife personnel.

Acknowledgements

We thank the personnel of Grenada's Forestry and National Parks Department, especially Aden Forteau, Alan Joseph, and Anthony Jeremiah. Additional logistical support and help in the field came from Drs. Reccia Charles, Claire Morrall, and Marie Rush of St. George's University, as well as from Tasha Brnak and Shawn Miller. We (BH, CSB) also recognize our collaboration with Wisconsin Lutheran College and the support received from Jerry and Kay Fischer. The helpful comments of an anonymous reviewer encouraged clarification of several important points. Fieldwork in Grenada has been generously funded by the Milwaukee County Zoological Gardens (CSB), Zoological Society of Milwaukee (CSB), Racine Zoological Gardens (BH), Thomas Torhorst Foundation (BH), Milwaukee Public Museum (RWH), and the Windway Foundation (RWH). We thank the Lazy Lagoon Guest House for continuing to provide the "herpetologists' discount." John Parmerlee produced the map and Mike Pauers generated the graph; we appreciate their efforts on our behalf.

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A Johnstone's Whistling Frog (*Eleutherodactylus johnstonei*) taking a meal.

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OVIX HZ

Group amplexing of large clusters (to >20 individuals) of Dennys' Treefrog (*Rhacophorus dennysi*) in Conghua, 150 km northeast of Dinghushan in March 2008, Guangdong Province, China.

Distribution and Behavior of Dennys' Treefrog (*Rhacophorus dennysi*) in Guangdong Province, China

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Vogt (1914) reported Dennys' Treefrog, *Rhacophorus dennysi* (Rhacophoridae), for the first time from Guangdong Province (as *Polypedates*), as later did Mell (1922). The range of *R. dennysi* was given as from southern China and westward to Burma in the Oriental Zone by Zhao and Adler (1993), but their records were not on or south of the Tropic of Cancer (TOC, ca. 23°26'). The previous southernmost record was Dayao Shan of Guangxi Province, bordering western Guangdong but still north of the TOC (Chen 1929; Ahl 1930, mistaken as "Vogt 1930" in Pope 1931). However, the range has been expanded due to more field surveys in recent years. These have generated new records from Guangdong (5 sites) and many provinces north and east of Guangdong, all north of the TOC, as well as Hainan, Guangxi, and northeastern Vietnam, all south of the TOC (Fei et al. 2009). The latter expansion is an unexpectedly southward trend in a reverse trajectory of the global warming phenomenon.

Dinghushan is located in central Guangdong Province, China, at 23°09'21"~23°11'30"N by 112°30'39"~112°33'41"E, just south of the TOC, a United Nation's Man and Biosphere (MAB) site. It is a remnant of old growth monsoonal hardwood forest. Although overlooked in the abovementioned new Guangdong records, *R. dennysi* was first reported from Dinghushan by Xu (2001), but the lack of voucher specimens was cause for concern (Li et al. 2009). On 21 and 23 July 2010, N. Qing with G.-H. Lin and W.-H. Lu with X. Qin, respectively, collected a male (Fig. 1) and an adult female, each during a typhoon rainy night, both at low elevation (~30 m) near the MAB headquarters. The male was ~4 m high

ZHI XIAO

Fig. 1. Dennys' Treefrog (*Rhacophorus dennysi*) from Dinghushan, south of the Tropic of Cancer. Collected in July 2010 in Guangdong Province, China.

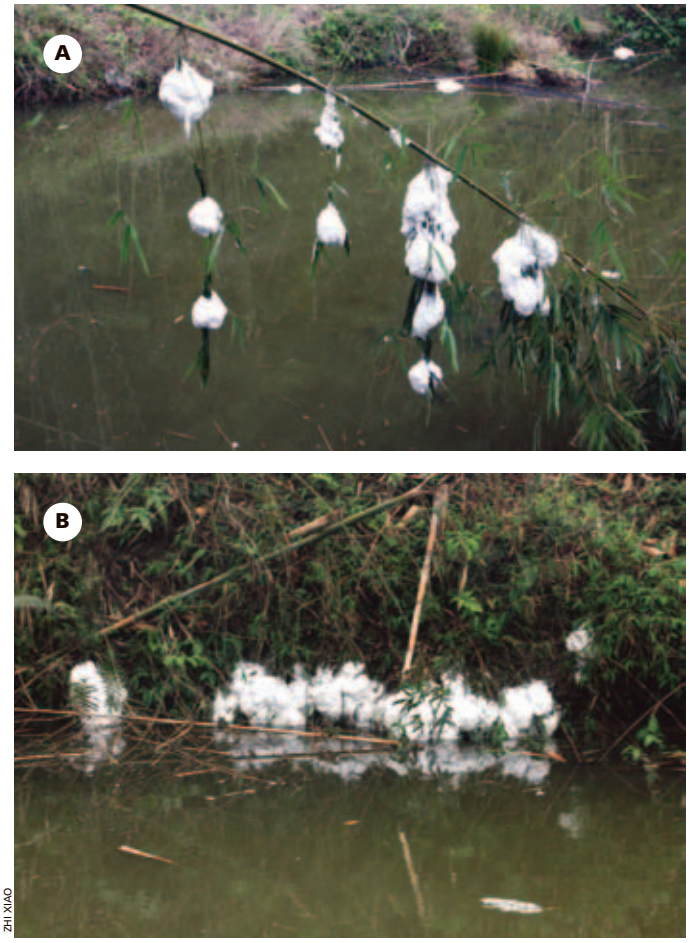

Fig. 2. Amplexing clumps of *Rhacophorus dennysi* hanging over (A) or near (B) water at Conghua, ~150 km northeast of Dinghushan in March 2008, Guangdong Province, China.

on a tree above a bridge (~7 m above the stream); it was not calling. The female was 3 m high on a banana leaf next to a shallow stream, typical of its habitat; no egg froth was found. On 21–22 February 2011, we heard numerous males calling from bushes surrounding a small fishpond near the MAB and caught amplexing pairs, but found no eggs. This is the earliest recorded mating behavior for the species.

Aggregative mating behavior is often observed in *R. dennysi*, with many amplexing pairs seen from March to May (Pope 1931, Li and Xiao 2011). On 18–19 March 2008 at Conghua, ~150 km northeast of Dinghushan, >2,000 individuals aggregated at four different sites near hillside streams or ponds in close proximity to a small mountain village (23°42'55"~23°44'14"N by 113°43'40"~113°51'46"E) (Fig. 2), ~500 m above sea level with trails to a nearby peak of >1,000 m. The frogs form clusters composed of as few as two pairs to 50 or more individuals (Fig. 3). Within these clumps, individuals can be in amplexus (one male on one female) or not. In the latter instance, multiple males (group amplexus) often are attempting to mate with one or a few females.

The frogs do not seem to be affected by onlookers. At one of the four sites, ~500 individuals each of *R. dennysi*, *Hylarana latouchii* (Brown Wood Frog), and *Bufo melanostictus* (Asian Common Toad) occurred in an artificial pond 30–50 m^2 in the center square of the village of Conghua (Fig. 4). The water in the pool was shallow at the time, despite a small feeder stream entering from the uplands, and full of garbage, but the density of frogs was so great that individuals of multiple species were amplexing in large groups. This is apparently a well-known spectacle that attracts tourists every March. However, we observed no frogs on 26 February 2011.

Additionally, *R. dennysi* engages in an interesting behavior, using its forelimbs to cover its eyes when disturbed at night and at times peeking out through the digits (Fig. 5), as if it is shy or does not like the light.

These distributional data confirm the 2001 record at Dinghushan and other records of 23°27'N by 111°53'E (Chang et al. 1997), 23°13'~23°23'N by 114°19'~114°27'E (Yang et al. 2001), 23°10'~25°31'N by 111°55'~114°50'E (Wen et al. 2002, Liang 2003), and 23°30'~23°95'N by 113°40'~114°38'E (Gu et al. 2007) from Guangdong Province. Our data are the southernmost for this species in Guangdong Province. All are close to either side of the TOC.

The Guangxi records and those from more southerly countries (e.g., Vietnam) in Fei et al. (2009) should be reexamined to be certain that they do not refer to *R. leucofasciatus*. This species was originally described by Liu and Hu (1962), but later synonymized with *R. dennysi* by Hu herself (Frost 1985). However, Fei et al. (2009) resurrected it based on fresh material from Fangcheng, Guangxi, at approximately 21°40'53"N by 107°50'50"E, south of the TOC. The range of this species is disjunct, with two sites in Guangxi and one in Sichuan Province. If Fei et al. (2009) examined all the relevant specimens and records to define the distribution of both species, these recent records are evidence of the southward expansion of *R. dennysi*. Interestingly Chen (1929) described "*Polypedates*" *feyi* from Yaoshan, a site north of the TOC in Guangxi and also the type locality for *R. leucofasciatus*, but the species was synonymized with *R. dennysi* by Pope (1931) without examining the type specimen — and his synonymy has been accepted.

We further question whether the Hainan Island record (recently supplemented by several additional unpublished reports from different nature reserves) is the result of an introduction attributable to economic expansion

Fig. 3. Group amplexing of *Rhacophorus dennysi* in a small cluster of >4 individuals (as seen here) or large clusters of >20 individuals (as on p. 74) at Conghua, ~150 km northeast of Dinghushan in March 2008, Guangdong Province, China.

WENHUA LU

Fig. 4. An artificial pond in Conghua (~150 km northeast of Dinghushan, Guangdong Province, China) where >1,500 individual frogs (~500 each of *Rhacophorus dennysi*, *Rana latouchii*, and *Bufo melanostictus*) congregated and formed multi-species amplecting masses in March 2008.

ZHEN-CHANG LI

Fig. 5. Light-shielding behavior of *Rhacophorus dennysi* from Xinfeng County (23°53'~23°59'N, 113°55'~114°03'E) in July 1996, Guangdong Province, China.

and tourism. Shi and Meng (2001) were the first to list it from Hainan, but we could not verify the "historical" record. Not until the 21st century was it collected at an altitude of 900 m around a guesthouse complex (Wang et al. 2007), which is the likely source for Fei et al. (2009). This species is seldom kept as a pet in China, and therefore is unlikely to be released to the wild. Although it is found in well forested, mountainous areas, where only a small number of tourists visit, the construction and landscaping of hotels and guest houses in these nature reserves are possible explanations for the presence of these frogs in Hainan, which might have been inadvertently introduced with building materials and horticultural plants, such as banana and bamboo varieties. Furthermore, another green treefrog (*R. yinggelingensis*) was recently described from Hainan (Chou et al. 2007). It closely resembles *R. dennysi*, and can be distinguished only by outer finger webbing. Careful examination of future records from that province will be necessary.

The discovery of *R. dennysi* at Dinghushan, Guangxi, Hainan, and other Asian countries south of the TOC could all be anthropogenic. First, this range expansion reverses that expected from global warming. Second, that this species was overlooked in the past is unlikely because early investigators found it abundantly in other areas of southern China and the sites of these new records within China had been visited by them. Such a sudden abundance is often typical of recent introductions. On the other hand, climatic changes might include factors unknown to us that favor the southward expansion of this treefrog. A molecular test among these populations of *R. dennysi* could reveal their origins. In the interim, however, with global climatic change and ecotourism-related development in mind, surveys documenting the apparent range expansion of this species in Guangdong Province are ongoing.

Acknowledgments

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THOMAS SCHREI

Abronia frosti is one of several species in the genus thought to have become extinct soon after its discovery.

Project Abronia: Protecting the Secretive Alligator Lizards of Guatemala

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Arboreal Alligator Lizards of the genus *Abronia* are among the most endangered species of lizards in the world (Campbell and Frost 1993). Of the 19 species included on the IUCN Red List (2010), one is critically endangered, six are endangered, three are vulnerable, two are of least concern, and the other seven could not be assessed because data are deficient. In Guatemala, the genus *Abronia* is comprised of ten species, eight of which are endemic (Ariano-Sánchez and Meléndez 2009). Project Abronia was initiated by the Guatemalan NGO Zootropic in late 2009, with the objective of protecting these cloud-forest-dwelling reptiles and their habitat. None of Guatemala's eight endemic *Abronia* species have been assessed using the IUCN Red List criteria; until recently, two species (*A. campbelli* and *A. frosti*) were thought to be extinct.

At Zootropic, we believe that research and environmental education are essential for effective conservation. Protecting nature requires more than science; people within the affected areas must be involved in order to ensure long-term success of our projects. So, along with the research field trips, workshops and environmental talks were held in the areas where the various species are located. This combination has produced some interesting results, and these secretive lizards have proven to be one of the best-kept "Jewels of Guatemala."

Abronia campbelli was first discovered in 1993 and thought to have become extinct shortly thereafter (Brodie and Savage 1993). In 2009, Zootropic researchers rediscovered individuals of this species in a highly disturbed oak forest (Ariano and Torres 2010). The remaining habitat consists of only 406 standing trees, leaving this highly vulnerable population subject to genetic isolation. Interviews with local villagers have revealed that the precarious state of the area is due to the felling of trees to facilitate cattle ranching. Management of this area for conservation purposes is extremely urgent.

Local inhabitants call *A. campbelli* "escorpión," which means scorpion. They believed it to be highly poisonous, and would usually kill any

MONICA TORRES-ALMAZÁN?

The future of conservation is the next generation. Children participating in this educational program at a school in Jalapa received t-shirts to facilitate the dissemination of the conservation message.

DANIEL ARIANO

Abronia campbelli was thought to have been extinct until its recent rediscovery. This adult is equipped with a small radio transmitter to track movements.

THOMAS SCHREI

Hatchling *Abronia campbelli* from the captive-breeding program at the Zootropic Herpetarium in Guatemala City.

lizard they encountered. Many myths existed about *A. campbelli*. They kill the trees, lightning will strike any tree with many lizards on it, any person who passes across the shadow of a lizard will die with 24 hours, and the lizard uses its tail to inject venom. Faced with such attitudes, environmental education capable of demystifying the species has been a priority. Once informed that their beliefs had no scientific basis, the local people reacted very well, showing great sympathy for these lizards

Along with habitat loss, another alarming threat is illegal trafficking. During our first field trip to the type locality, we encountered foreigners who were looking for these lizards. Unfortunately, at that time, we did not have enough information to realize what these people were doing at the site. Additional information has led us to believe that these people were smugglers who were looking for *A. campbelli* for commercial trade in Europe. Interviews with local villagers have revealed that smugglers took at least five *A. campbelli*.

We also have secured five pairs of this species for a captive-breeding program operated at the Zootropic Herpetarium located in Guatemala City. Between March and April 2010, four females gave birth to an average of 10.5 offspring. The release of the neonates into their natural habitat was organized with the assistance of local people. We chose trees that were not too isolated from other oaks and that were within areas where trees are less likely to be disturbed by humans. Some of our females seem to be pregnant again this year, so we hope the breeding program will continue to be a success.

One of the greatest achievements of the project is the realization of conservation agreements with owners of the properties that are within the habitat of *A. campbelli.* This year, we plan to start a breeding program *in situ*. Also, specific areas will be strictly protected for the species, while other areas will be slated for restoration and reforestation. Because the isolation of suitable trees is of concern for the genetic variability of the species, we plan to increase connectivity by planting native fast-growing trees between the existing oaks. We also plan to create artificial corridors by joining the tops of the remaining oaks with ropes that can be covered with thick masses of Spanish Moss (*Tillandsia usneoides*). Telemetry research that we are initiating in the area should help us identify patterns of behavior in the wild and provide means by which we can judge the utility of our proposed measures.

Abronia meledona is another species of concern to the project. People living within the range of this animal also call it "escorpión," believe it is

MONICA TORRES-ALMAZÁN?

A local villager learns that *Abronia meledona* is anything but dangerous.

LESTER MELÉNDEZ

Some populations of *Abronia fimbriata* appear to be healthy — thanks to the private preservation of suitable habitat.

very poisonous, and hold many of the same erroneous beliefs that are held for *A. campbelli*. Environmental education talks also have been an important component of our conservation strategy in this area. During these workshops, deforestation was identified as the main threat. The people of the community mentioned that most deforestation is a result of logging to open pastures for raising cattle, but they also recognize that their intensive use of firewood has increased degradation of the area. Fortunately, however, this species does not seem to be as threatened as some congeners since local private nature reserves have enabled the preservation of sufficient forest cover in the area.

Abronia fimbriata is yet another species on which the project has focused. As a result of workshops, we have received information about the presence of these lizards in four different private reserves. Some of the individuals we have observed are juveniles, indicating that these populations are reproducing and likely to be in good condition — thanks to the private preservation of suitable habitat.

The main threat affecting *A. fimbriata* is habitat loss due to the rapid advance of the agricultural frontier (mainly Leatherleaf [*Chamaedaphne calyculata*] cultivation). The owners of the natural reserves perceived themselves as part of the solution to this problem because the area's natural reserves help mitigate these types of changes in land use through conservation of large areas of forest. Illegal traffic of the species also has been identified as a potential threat; witnesses report that animals have been taken in the past.

Abronia frosti is another species thought to have become extinct soon after its discovery (Campbell et al. 1998, Campbell and Mendelson 1998). Fortunately, a subadult was found in October 2010 on a recently cut oak within a cloud forest remnant near the original type locality (Ariano et al., in press). This individual was captured for the initiation of a captive-breeding survival assurance colony — part of a short-term conservation program for this species. In this case, local people feared these lizards and used to kill them on sight, believing them to be indicators of bad luck. Many also thought that they were poisonous.

Abronia frosti is threatened mainly by habitat loss due to selective cutting of various species of oaks, compounded by reforestation efforts using non-native trees. Local people acknowledge that they are the cause of deforestation. They need the firewood to survive, but quickly recognized that the best strategy to reduce this threat is reforestation. The community leader informed us that they were struggling to reforest the area. Because it is a community forest, all communities must agree on reforestation before it can be implemented. *Abronia frosti* is not extinct, but strong conservation measures are urgent.

Within a short period of time Project Abronia has already provided hope for the survival of seriously endangered species of *Abronia* in Guatemala. With diligence, luck, and help from local and international partners, we may yet recover further species that are thought to be extinct, and, given the secretive nature of these animals, discover other species that are as yet unknown to science.

THOMAS SCHREI

Abronia frosti is threatened mainly by habitat loss due to selective cutting of oak trees for firewood.

MONICA TORRES-ALMAZÁN?

Environmental education is essential for effective conservation. Protecting nature requires more than science; people within the affected areas must be involved in order to ensure long-term success of our projects. This workshop with local villagers addressed the conservation concerns for *Abronia frosti*.

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This Project Receives IRCF Support.

TOM WIEWANDT

Using a long-term, natural history-based approach, we observed microgeographic differences in body size, growth, diet, and reproduction among three populations of Tiger Rattlesnakes (*Crotalus tigris*).

Microgeographic Variation in Tiger Rattlesnake Ecology and Life History: The Importance of Long-Term, Natural History-Based, Multiple-Population Research

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We studied multiple populations of Tiger Rattlesnakes (*Crotalus tigris*) in the Sonoran Desert from 1997–2010, using mark-recapture and radiotelemetry to obtain a robust data set on various aspects of Tiger Rattlesnake biology. We report on variation in body size, diet, growth, and reproduction at three intensively studied sites near Tucson, Arizona, USA. We discuss possible reasons for observed differences within and among populations, and emphasize the importance of long-term studies that encompass multiple populations to better understand effects of environmental variation and local adaptation. We also stress the need to incorporate an intensive natural history-based approach to elucidate patterns that can subsequently be examined using a more focused, question-driven approach.

A review of the literature reveals that, with few exceptions (e.g., Fitch 1999), most of what we know about snakes comes from relatively short-term, single-population studies (see discussion in Parker and Plummer 1987). Studies on multiple populations of snakes have tended to focus on geographic variation in populations separated by relatively long distances, often from disparate habitat types (e.g., Plummer 1987, Gregory

DON SIAS

The view overlooking the ninth green at Stone Canyon. Note the artificially mesic habitat associated with the golf course.

and Larsen 1993, Ashton 2001, Luiselli et al. 2001, Zuffi et al. 2009). Comparatively few studies have examined microgeographic variation (see King 1993, Beaupre 1995, Jenkins et al. 2009) in snake populations, especially from similar habitats (see Kephart 1982, Meshaka and Delis 2010). In spite of these shortcomings, ecologists recognize the need to examine long-term variation within and among populations of a species if we are to understand the critical roles played by environmental variation and local adaptation (Stearns 1992).

In 1997, when we began to study Tiger Rattlesnakes (*Crotalus tigris*) in the Sonoran Desert of Arizona, our goal was to conduct a long-term study that would enable us to learn as much as possible about the secret lives of these seemingly elusive snakes (cf., Goode et al. 2008). Fourteen years later, with countless hours spent in the field, at times practically living with our research subjects, we have amassed a rich dataset on multiple populations. Using a classic natural history approach, we have relied on intensive field observations to uncover patterns in nature, often followed by question-driven research designed to gain a more thorough understanding of Tiger Rattlesnake ecology (e.g., Greene 2005). In spite of criticisms from those wedded to experimental hypothesis testing, we unapologetically favor a rigorous natural history approach, because it often leads to a better understanding of the life histories of free-ranging animals. Also, although increasingly overlooked, hard-won natural history data often are critical for conservation and key for identifying patterns that can lead to the development of hypotheses that can be tested in a more focused scientific framework, even in some cases disentangling cause and effect through field experimental manipulation (e.g., Bartholomew 1986).

In this paper, we provide selected data on important aspects of Tiger Rattlesnake ecology and life history from three intensively studied populations subjected to different local environmental conditions. In one population, a subset of individuals has been exposed to anthropogenic influences (i.e., a low-density residential development and associated golf course) that appear to have led to dramatic changes in fundamental life history traits. These changes are likely due to greatly increased productivity brought on by year-round irrigation of the golf course and landscaping associated with roads, public facilities, and private residences.

Methods

Study Sites.—We collected data on Tiger Rattlesnakes from several sites throughout the Tucson Basin and southern Arizona. However, in this paper, we only included data from three populations located in the Rincon and Tortolita Mountains (Fig. 1), because these were the only sites where we conducted intensive mark-recapture and radiotelemetry research. The two sites within the Rincon Mountains, Tanque Verde Ridge (TVR) and Rocking K Ranch (RK), were originally chosen as part of a project investigating effects of urban development on Tiger Rattlesnakes along the boundary of Saguaro National Park along the southeastern edge of Tucson. The two sites are situated approximately 4 km apart. The Tortolita Mountain site, Stone Canyon (SC), is located on the northwestern side of Tucson, approximately 50 km from the other two sites. Stone Canyon is a large, affluent development, which when completed will consist of a resort, golf course, and over 450 residential estates situated on one- to five-acre lots. The golf course was built in 2000, and as of 2010, approximately 150 homes were constructed. All three sites consist of massive rocky ridges with steep rocky slopes dissected by relatively small ephemeral washes, some of which are characterized by well-developed xeroriparian vegetation. Vegetation is typical of Sonoran Desertscrub, Arizona Upland Subdivision (Turner and Brown 1982). Common plants include Saguaro (*Carnegia gigantea*), Foothill Paloverde (*Cercidium microphyllum*), Brittlebush (*Encelia*

DON SIAS

A Tiger Rattlesnake (*Crotalus tigris*) in an ambush posture waits for a potential meal. We have documented interpopulation variation in Tiger Rattlesnake diet at three sites.

JOHN F. BINNS

Fig. 1. Map of Tucson, Arizona and surrounding mountain ranges, showing the locations of our three study sites (RK = Rocking K, TVR = Tanque Verde Ridge, SC = Stone Canyon).

farinosa), Prickly Pear and Cholla (*Opuntia* spp.), and Velvet Mesquite (*Prosopis velutina*). The elevational range is approximately 850–1,100 m.

Capture, Handling, and Marking.—We encountered Tiger Rattlesnakes while road cruising, during foot surveys, and while radiotracking a large number of snakes implanted with radiotransmitters. We captured rattlesnakes with tongs and transported them to the lab in cloth snake bags placed inside coolers. We permanently marked snakes by injecting a PIT tag under the skin, sealing the injection site with superglue. We assigned each snake an identification number corresponding to the sequence in which it was captured, and a unique paint mark applied to the dorsal half of the first 3–4 rattle segments conveyed this number. This allowed us to identify snakes in the field without capturing them, and it enabled us to determine shedding frequency.

Data Collection.—In the laboratory, we placed rattlesnakes in a clear plastic restraining tube and anesthetized them using 1–2 ml isoflurane (Abbott Laboratories, Abbott Park, Illinois). We contend that anesthetizing rattlesnakes is critical, because it facilitates accurate data collection, eliminates or reduces stress and pain associated with handling, and minimizes the likelihood of harm to both rattlesnakes and researchers. Accurate SVLs are essential for reliable quantification of growth, especially in adult Tiger Rattlesnakes, which typically grow in fractions of a millimeter per month. Anesthesia also facilitates collection of feces, which are easily removed from the hindgut via gentle and repeated pressure applied toward the cloaca. We washed and sorted fecal samples into identifiable prey remains, consisting of hair, scales, claws, bones, teeth, and the occasional feather. For the purposes of this paper, we have only provided data on fecal samples containing hairs and scales, because they are easily identifiable, and can be unambiguously assigned to either mammal or lizard, by far the two most important prey groups of Tiger Rattlesnakes.

Assessment of reproductive condition in females, via palpation of follicles, ova, or embryos, also is far more reliable in anesthetized individuals. We have compared data from palpation to ultrasound readings, and we have found this manual method to be highly accurate (M. Goode, unpubl. data), although fully formed embryos can be difficult to palpate even in a fully anesthetized snake. We assessed reproductive condition either in the fall, when gravid females contain small, hard follicles before entering hibernation, or in the spring, when gravid females contain larger, vitellogenic follicles upon emergence from hibernacula. Tiger Rattlesnakes tend to give birth in rock outcrops, making it difficult to obtain data on litters. However, diligent radiotracking of gravid females enabled us to obtain such information for numerous snakes. In a few cases, we assumed that a gravid female gave birth, even though we did not see the litter, because the recaptured female had lost a significant amount of mass. Similar decreases in mass were consistent with those in snakes known to have given birth and for which we were able to obtain post-parturient masses.

Results

Body Size (SVL).—We drew upon our rich mark-recapture data set (Table 1) to examine within- and among-population variation in SVL, which varied among the three populations, and within the SC population, where Tiger Rattlesnakes associated with the golf course environment were much larger than their off-course counterparts (Fig. 2).

Growth.—We used ANCOVA with initial snout-vent length as a covariate to detect differences in growth rates. Analyses revealed no difference in growth rates among the three populations (Fig. 3a). However, when comparing SC snakes, individuals associated with the golf course and

JOSH CAPPS

Overspray and runoff from the constant irrigation required to maintain turf have created permanent riparian areas along Stone Canyon's fairways and greens.

Table 1. Numbers of captures and recaptures of Tiger Rattlesnakes (*Crotalus* tigris) at our three study sites and other locations in Arizona from 1997–2010 (RK = Rocking K, TVR = Tanque Verde Ridge, SC = Stone Canyon, Catalinas = Santa Catalina Mountains, Tucsons = Tucson Mountains). Only data from RK, TVR, and SC were used in analyses.

Site	Captures	Recaptures
RK	59	24
TVR	145	77
Catalinas	126	1
SC	646	532
Tucsons	61	0
Other	72	0
Total	**1,109**	**634**

DON SIAS

Body sizes of Tiger Rattlesnakes (*Crotalus tigris*) varied among populations and within the Stone Canyon population.

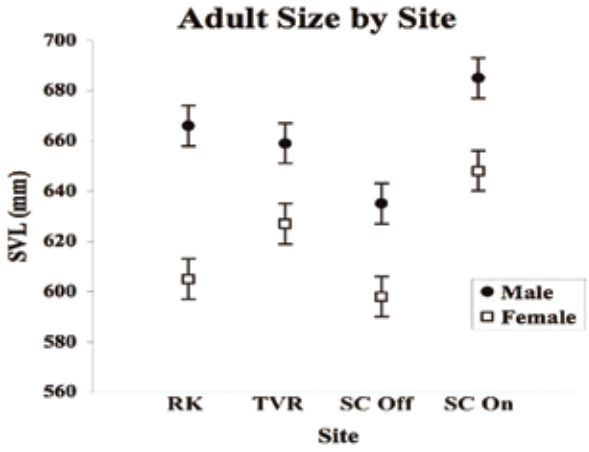


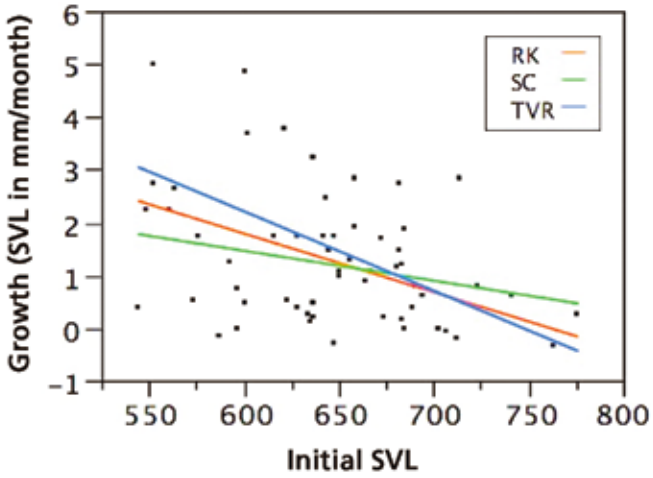
Fig. 2. Average adult male and female Tiger Rattlesnake (*Crotalus tigris*) body sizes (SVL = snout-vent length) at RK, TVR, and SC from 1997–2010 (RK = Rocking K, TVR = Tanque Verde Ridge, SC = Stone Canyon). The SC population is divided into those snakes with home ranges that include part of the golf course (SC-on) and those with home ranges that do not include part of the golf course (SC-off).

development grew significantly more rapidly than their off-course counterparts (Fig. 3b). We only used radiotransmittered snakes for on- and off-course comparisons, because we could be certain that off-course snakes never included the golf course in their home ranges.

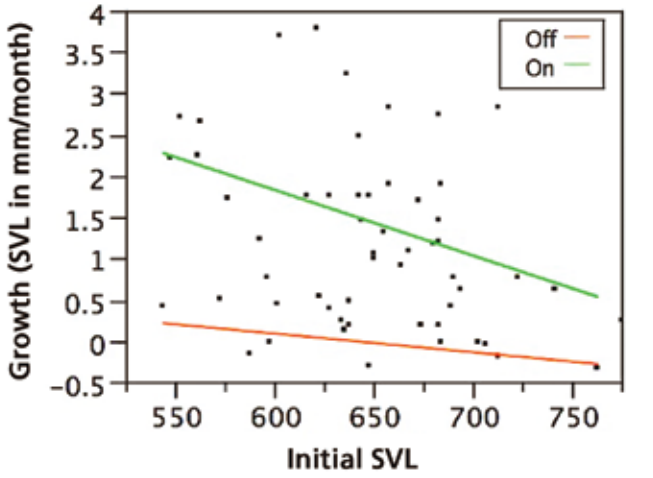
Diet.—Fecal analysis revealed important among-population differences in diet (Fig. 4). Tiger Rattlesnakes at TVR were primarily small-mammal eaters, whereas rattlesnakes at RK consumed primarily lizards, even though the two populations are only 4 km apart. At SC, rattlesnakes ate a far greater proportion of mammals, but the difference between on- and off-course snakes was negligible.

Reproduction.—Palpation of female Tiger Rattlesnakes revealed slight among-population variation in reproductive status. However, we observed a dramatic increase in within-population variation at SC (Fig. 5), where a roughly two-fold increase in the proportion of gravid females was associated

A Tiger Rattlesnake (*Crotalus tigris*) consuming a Western Whiptail (*Aspidoscelis tigris*). Tiger Rattlesnakes consumed lizards in greater proportions at Rocking K than at Tanque Verde Ridge or Stone Canyon.



Source	DF	Sum of Squares	F Ratio	Prob > F
Site	2	1.151030	0.4065	0.6681
InitialSVL	1	14.797037	10.4516	0.0022
Site*InitialSVL	2	2.691094	0.9504	0.3933



Source	DF	Sum of Squares	F Ratio	Prob > F
Off/On	1	9.5082340	13.1397	0.0013
InitialSVL	1	1.9868555	2.7457	0.1100
InitialSVL*Off/On	1	0.6457620	0.8924	0.3539

Fig. 3. A. ANCOVA of growth rates of Tiger Rattlesnakes (*Crotalus tigris*) at three sites from 1997–2010, using initial SVL as a covariate to detect differences in growth rates (RK = Rocking K, TVR = Tanque Verde Ridge, SC = Stone Canyon). **B.** Within-population comparison of growth rates for on- and off-course snakes at SC from 2002–2010. We considered on-course snakes to be those with home ranges that included part of the golf course and off-course snakes to be those with home ranges that did not include part of the golf course.

Table 2. Mean litter sizes (± 1 SE) of Tiger Rattlesnakes (*Crotalus tigris*) at RK, TVR, and SC (RK = Rocking K, TVR = Tanque Verde Ridge, SC = Stone Canyon). The SC population is divided into those snakes with home ranges that include part of the golf course (SC-on) and those with home ranges do not include part of the golf course (SC-off).

Site	Mean Litter Size
RK	2.2 ± 0.3
TVR	2.4 ± 0.4
SC-on	3.4 ± 0.5
SC-off	2.4 ± 0.3

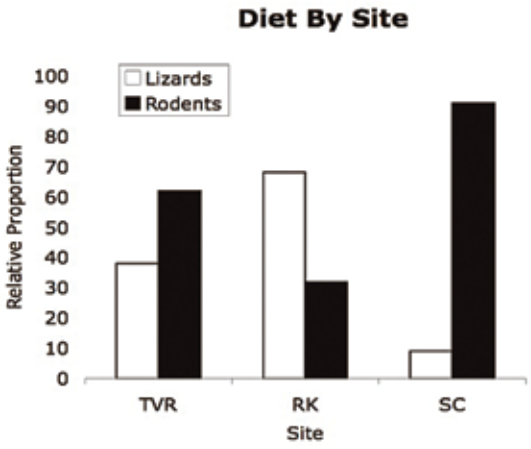


Fig. 4. Proportions of mammals and lizards in the diets of Tiger Rattlesnakes (*Crotalus tigris*) at RK, TVR, and SC based on examination of fecal samples (RK = Rocking K, TVR = Tanque Verde Ridge, SC = Stone Canyon).

An adult Tiger Rattlesnake (*Crotalus tigris*) eating a White-throated Woodrat (*Neotoma albigula*). Snakes at Stone Canyon ate a far greater proportion of small mammals than at the other two sites.

with the golf course and development. Mean litter size (a critical life history trait with obvious fitness consequences) of snakes occupying the golf course and development portion of SC was 3.4, which represents an approximately 30% increase over off-course, TVR, and RK snakes (Table 2).

Discussion

Using a long-term, natural history-based, intensive field approach, we were able to uncover important within- and among-population differences in Tiger Rattlesnake ecology and life history. Our findings suggest that life history traits are relatively plastic, apparently responding to changes in local environmental and ecological conditions, even over relatively short distances. Although our data will eventually be rigorously analyzed in the context of life history theory, our goal here was to simply describe micro-geographic differences observed in Tiger Rattlesnakes populations.

The most striking results from our research were the consistent differences found in snakes living within the golf course and development area at SC. This area is dramatically different than TVR, RK, and nearby off-course sites, because it is characterized by a growing residential development and associated golf course. Data on water availability at SC indicate that seasonal drought is essentially eliminated at the golf course site (Fig. 6). In addition, intensive irrigation of mostly native vegetation along the golf course and roads, and in landscaped areas around public facilities and homes, results

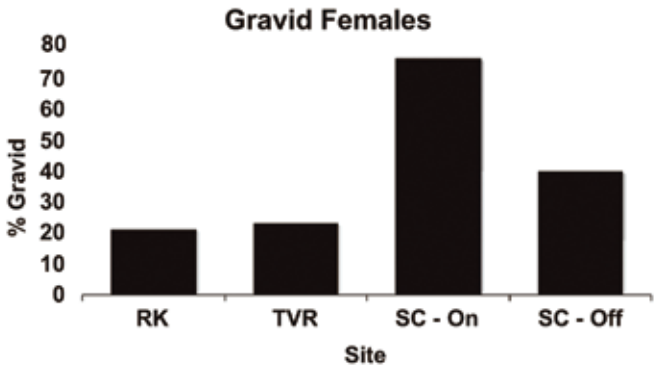


Fig. 5. Among-population comparison of the reproductive status of female Tiger Rattlesnakes (*Crotalus tigris*) at three sites and within-population comparison at SC from 1997–2010 (RK = Rocking K, TVR = Tanque Verde Ridge, SC = Stone Canyon). The SC population is divided into those snakes with home ranges that included part of the golf course and off-course snakes to be those with home ranges that did not include part of the golf course.

in thick, mesic tracts of vegetation that essentially act as permanent riparian areas in an otherwise dry environment. The dramatic difference between natural and irrigated areas is most pronounced in spring and early summer, when the Tucson region receives only trace precipitation. In essence, the existence of year-round water at SC greatly extends the active season of many species. In addition, unusually high productivity leads to increased plant reproduction, providing forage and cover for a wide variety of animals. Apparently, Tiger Rattlesnakes are taking advantage of this enhanced resource environment, allocating extra energy to growth and reproduction. Indeed, 8 of 16 female Tiger Rattlesnakes from on-course areas at SC have given birth in two successive years, and one individual produced a litter in each of three successive years. In comparison, only 5 of 31 females from all other sites combined have been gravid in successive years.

In the case of diet and prey availability, systematic surveys indicate that the relative abundance of lizards is greater at RK than at TVR, which corresponds to the relative proportion of lizards consumed by Tiger Rattlesnakes at both sites (Goode and Wall 2002). Small-mammal trapping at all three sites indicates that relative abundance of small mammals at SC

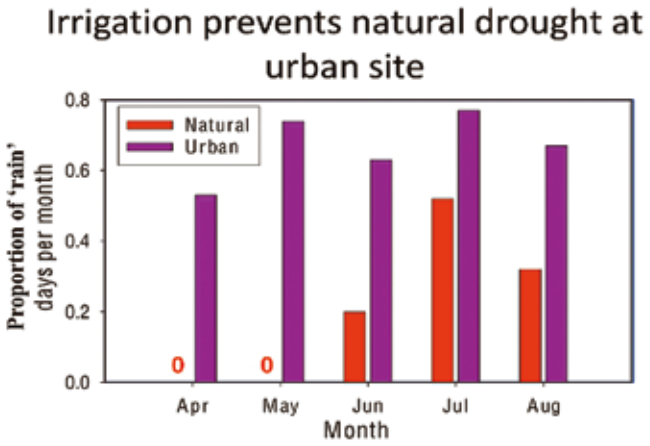


Fig. 6. "Rainfall" (i.e., irrigation) patterns at Stone Canyon verses natural rainfall patterns in Tucson, Arizona in 2007. Courtesy of Jon Davis and Dale DeNardo, ASU.


PAUL CONDON

Two neonate Tiger Rattlesnakes (*Crotalus tigris*). Litter sizes from females occupying the golf course were approximately 30% higher than those from other populations.

DON SIAS

Although Tiger Rattlesnakes (*Crotalus tigris*) appear to be benefiting from the energy-rich environment of the Stone Canyon golf course, they also face risks posed by increased human activity.

is dramatically higher than at TVR and RK, with trap success rates ranging from as low as 5% at RK to as high as 75% at SC (M. Goode, unpubl. data). Again, these differences are likely attributable to stark differences in water availability, leading to increased seed and leaf production and higher rodent populations at SC.

Our study underscores the importance of long-term studies on multiple populations. A study of shorter duration might have led us to a erroneously conclude that Tiger Rattlesnakes at TVR feed primarily on small mammals and gravid females have small litters every 2–5 years. By adding the RK population, we discovered that Tiger Rattlesnakes found only 4 km away actually consumed more lizards than small mammals, even though they occurred at the same elevation and were using an essentially identical vegetative community. Furthermore, dietary analysis at SC revealed yet another difference, with snakes consuming small mammals in much higher proportions than in the other two populations. Documenting interpopulation variation in diet is important, because it provides insight into the fundamental ecology of an organism, and allows for predictions to be made about behavior, physiology, and reproduction (Taylor et al. 2005).

Tiger Rattlesnakes clearly are responsive to changes in their environment, and snakes living in an energy-rich environment (e.g., SC on-course) are taking advantage of additional resources to increase their reproductive output. However, concluding that golf courses and developments are beneficial for Tiger Rattlesnakes would oversimplify the complexity of this relationship, and we caution against such an interpretation. Data from SC indicate that humans regularly kill snakes, including Tiger Rattlesnakes. Indeed, mortality rates in general appear to be much higher at SC than TVR and RK, including what appears to be natural predation. Road mortality at SC also has been relatively high, and it continues to increase as more homes are built. The critical question from a conservation standpoint is whether or not increased female reproductive output at SC can offset increased mortality. Will SC become an ecological trap, providing Tiger Rattlesnakes with all their needs only to bring them into contact with humans? Only a long-term study such as ours will be able to answer that question.

Acknowledgements

We thank the cadre of field assistants who have helped us conduct research on Tiger Rattlesnakes over the past 14 years. In particular, we thank Kirk Setser, Melissa Amarello, Jeff Smith, and Mike Wall, all of whom kept the project afloat under often-difficult circumstances, working long hours in the field and providing thoughtful insight into methodology and interpretation of results. We are indebted to Larry Norris for his generous support of our research program, enabling us to build the momentum we needed to be successful. We express our sincere thanks to the staff at Saguaro National Park, and the owners of the Rocking K Ranch. We are particularly grateful to Dick Maes, Todd Huizinga, and the staff at Stone Canyon for generously providing us with a golf cart and a trailer to make our work much easier. We thank the Arizona Game and Fish Department, National Fish and Wildlife Foundation/United States Golf Association Wildlife Links Program, Western National Parks Association, Desert Southwest Cooperative Ecosystem Studies Unit-National Park Service, and the Rocky Mountain Region of the National Park Service for providing funding to carry out this research.

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Young Aruba Whiptail (*Cnemidophorus arubensis*) from Aruba sitting on a tonalite block (a type of andesite rock). Distinguishing the sexes is difficult in young and subadult animals. When males become larger, they change color from yellow-brown or light brown to gray and blue. In an animal of this size that would be noticeable, thus the lizard in the picture is very likely a female.

The Teiid Lizards of Aruba, Curaçao, Bonaire (Dutch Caribbean), and the Península de Paraguaná (Venezuela)

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Photographs by the author.

Herein I discuss the larger teiid lizards of the genera *Ameiva* and *Cnemidophorus* on the Dutch Leeward Islands (Aruba, Curaçao, and Bonaire) and those on the nearby Península de Paraguaná in Venezuela. Lizards in the genus *Cnemidophorus* are generally called "Whiptail Lizards" or "Racerunners," whereas those in the genus *Ameiva* are called "Jungle Runners." The genera differ in the number of rows of ventral scales and in the structure of the bones in the tongue. However, in some DNA analyses, *Ameiva* and *Cnemidophorus* do not separate clearly. Some members of the Neotropical "*C.*" *lemniscatus* species group appear to be more closely related to some species of *Ameiva* and *Kentropyx* than to many species of *Cnemidophorus* (Reeder et al. 2002).

Map showing the locations of Aruba, Bonaire, and Curaçao in relation to the Paraguaná Peninsula of Venezuela.

Both *Ameiva* and *Cnemidophorus* are diurnally active lizards that constantly forage to find food such as insects, other arthropods, carrion, and sometimes plant material. On occasion, they can even be cannibalistic. *Ameiva ameiva* will eat fruit, and *C. lemniscatus* has been observed eating the flower petals of cacti in the genus *Opuntia* (Mijares-Urrutia et al. 1997). Surprisingly, some island varieties of *Cnemidophorus*, such as *C. arubensis, C. ruthveni*, and *C. murinus* are to a large degree herbivorous. The colon in *C. murinus* is larger than in other species of Whiptails and is clearly adapted to a herbivorous diet (Dearing 1993). Herbivory in lizards is relatively unusual and is often associated with an increase in body size. The fact that these island *Cnemidophorus* are largely herbivorous enables them to reach much higher population densities than would otherwise be the case in an arid environment with insufficient numbers of insects and other arthropods to maintain such high population densities of relatively large lizards.

The Península de Paraguaná has a surface area of approximately 2,612 km^2 (without the isthmus connecting the peninsula to the mainland), Aruba is about 190 km^2, Curaçao 444 km^2, Klein Curaçao 1.2 km^2, Bonaire 282 km^2 (including Klein Bonaire with 7 km^2). At various times during its history, Paraguaná was an island. In the late Pleistocene or early Holocene, it became connected to the mainland by a narrow strip of dunes. During the ice ages, when sea levels were much lower, it was part of the South American mainland. Aruba might at one time have been connected to the mainland; if this was the case, it was quite long ago and lasted only a relatively short period of time. Alternatively, it might always have been an island, but at times separated from the mainland by only a very narrow strait (van Buurt 2005). Curaçao and Bonaire were never connected to the mainland.

These various degrees of isolation were conducive to the development of endemic species and subspecies. Aruba has three endemic reptiles, *Cnemidophorus arubensis, Phyllodactylus julieni*, and the Aruba Rattlesnake, *Crotalus unicolor*. *Anolis lineatus* is endemic to Aruba and Curaçao. Curaçao and Klein Curaçao have the endemic *Cnemidophorus murinus murinus*, whereas *C. murinus ruthveni* is endemic to Bonaire and Klein Bonaire. The snake *Liophis triscalis* is endemic to Curaçao. The geckoes *Phyllodactylus martini* and *Gonatodes antillensis* are endemic to Curaçao and Bonaire, and *G. antillensis* also is found on Klein Curaçao. Paraguaná has one endemic reptile, the sphaerodactyline *Lepidoblepharis montecanoensis*, which is found in the Reserva Biológica Montecano (Markezich and Taphorn 1994).

Aruba

The Aruba Whiptail Lizard (*Cnemidophorus arubensis*) is locally called Kododo. Used for both males and females, this old Caquetío name is also used on Bonaire for *C. ruthveni*. *Cnemidophorus arubensis* is a common lizard found practically everywhere. Males are gray or gray with some brown

"Paw-waving" behavior in a young Aruba Whiptail (*Cnemidophorus arubensis*) from Aruba. In the Honduran Bay Islands, similar behavior in *C. lemniscatus* is responsible for the local name "Shaky-Paw."

Cunucu Arikok, characterized by large tonalite blocks (a type of andesite rock) that are typical over much of the Aruban landscape.

Rainbow Whiptails (*Cnemidophorus arenivagus*) have been introduced in Aruba, where they have gradually extended their range in the southeastern part of the island; this one was photographed in the area around Vader Piet.

Ameiva bifrontata in Aruba vary in color; usually they are light khaki-brown, which gives them their local name "Koffie cu lechi"(= coffee with milk). A bit of light green and some blue on the sides is often hardly noticeable. A mite can be seen on the jaw of the individual in the top photograph. This mite probably belongs to the family Tromiculidae (Chigger Mites). The individual in the bottom photograph is a bit more grayish and has some faint stripes on the lower back. Such markings are better developed in *A. bifrontata* from the Paraguaná Peninsula; individuals from there also have noticeably more blue on their sides.

and have white dots with a fine blue edge. Males also have blue patches on the hindlimbs and have blue tails. Females are brown or khaki-brown and have similar dots, but no blue tails. The blue colors in males vary in brightness, with sexually dominant males brighter. While probably true in the other island Whiptails, this is particularly notable in this species.

Whiptails stop now and then and wave a front limb in the air. This behavior, which takes place when they are confronted with a possible threat (even a human being), is probably comparable to head-bobbing in iguanian lizards such as iguanas and anoles. It may signify something like "don't waste your time trying to catch me, I have already spotted you." However, if one approaches an individual too closely, it will not wave its leg, presumably in order to avoid undue attention. This signaling behavior also might be employed during sexual overtures to a female or when confronting another male. Front paw-waving behavior is quite frequent in *C. arubensis* but less so in *C. ruthveni* and even less frequent in *C. murinus*. Arubeans say that their lizard is friendlier.

The Rainbow Whiptail Lizard (*Cnemidophorus arenivagus*) was introduced on Aruba around 1950, when it was discovered near the oil jetties in San Nicolas (Lammarée 1970). At the time, it was described as *C. lemniscatus*. When Markezich et al. (1997) described a new species from Paraguaná and named it *C. arenivagus*, they implied that the lizard on Aruba would be the same species. While working on the Dutch version of my *Field Guide to the Amphibians and Reptiles of Aruba, Curaçao and Bonaire*, which was published in 2001, and also on the English version, published in 2005, I decided against using this name and deferred judgment on this matter, mainly because the photograph of the animal in Markezich et al. (1997) seemed to have much more lateral khaki coloration than the animals on Aruba and also since the animals on Aruba came from around an oil jetty where ships were arriving from several areas where *C. lemniscatus* lives. However, G.N. Ugueto (pers. comm.) noted that the individual illustrated in Markezich et al. was atypical and not representative of the most common coloration. Furthermore, on the basis of a photograph I took at Vader Piet on Aruba in August 2008, he confirmed the identity of the species as *C. arenivagus*.

In the 1990s, these lizards were found in areas with somewhat sandy soil around San Nicolaas, Cura Cabai, Mabon, Brazil, at the location of the old airfield "de Vuist," and on and around the Aruba Golf Club. Today, the range seems to have expanded. In 2008, I saw it at Vader Piet and it also was reported near Guadirikiri. In 2010, F. Franken (pers. comm.) saw several at Santu Largu, Savaneta. On the other hand, the "de Vuist area" has been developed for residential housing and the lizards seem to have disappeared. This species does not displace *C. arubensis*, establishing only a precarious foothold in areas with sandy soil — and even in such areas it is not very common.

On Aruba, *Ameiva bifrontata* is called "Koffie cu lechi" (= coffee with milk) in reference to its color, but the name "Vloem" or "Floem" is sometimes used as well. *Ameiva bifrontata* is predominantly light khaki-brown with a light green or grayish-green infusion on the head and front of the body. Some have questioned whether *A. bifrontata* was introduced in Aruba or whether it is indigenous. While Wagenaar Hummelinck was working

Male (top) and female (bottom) Aruba Whiptails (*Cnemidophorus arubensis*) from Aruba. As males mature, they change in color from yellow-brown or light brown to gray and blue.

A Blue Lizard (*Cnemidophorus lemniscatus splendidus*) from the Fundo San Francisco on the Paraguaná Peninsula of Venezuela.

on Aruba for his dissertation in the late 1930s, he encountered this lizard only around Oranjestad, which led him to conclude that it was very likely a recently introduced animal. However, he also noted small differences between the Aruba lizards and those he had seen in Paraguaná (Wagenaar Hummelinck 1940). Ruthven (1924) mentioned that *A. bifrontata* had been collected on Aruba by Cope in 1885 and also by Dr. H. Burrington Baker in 1922. Schall (1973) found *A. bifrontata* all over Aruba in the early 1970s.

Curaçao

The Curaçao *Cnemidophorus murinus* is larger than *C. arubensis* and also somewhat larger than *C. ruthveni* on Bonaire. These lizards are light gray with blue on the feet and tail and some blue on the head. Large males are locally called Blausana, Blaublau, or Blòbò, which is derived from the Dutch word blauw (= blue). Blòbò is also used as a derogatory name for the police, who have blue uniforms. In dominant males, the blue is brighter, although the brilliance of the blue seems to vary during the year. Juveniles are brown and the females remain brown, sometimes with a slight shade of gray. Females and juveniles are called Lagadishi, which is also a general name for lizard or lizards. Lagadishi is derived from either Portuguese "lagartixa" or Spanish "lagartija," which in turn go back to Latin "lacerta." These lizards are very common and are found practically everywhere. Female *C. murinus* lay only one large egg at a time. This also holds true for *C. arubensis* (Schall 1983) and *C. ruthveni*. Might this be an adaptation to increase the odds of young surviving in an arid climate? A similar adaptation is found in Green Iguanas (*Iguana iguana*). Clutch size is smaller but eggs are larger in females from Curaçao when compared to mainland iguanas (van Marken Lichtenberg and Albers 1993).

Male (top) and female (bottom) Curaçao Whiptails (*Cnemidophorus murinus*). Note the red mites in a mite pocket behind the hindleg and on the tail of the male. These probably belong to the family of the Tromiculidae (commonly known as Chigger Mites).

Juvenile Curaçao Whiptail (*Cnemidophorus murinus*) eating a Prickly Pear (*Opuntia* sp.) flower.

Large *Melocactus macracanthus* from Curaçao. These cacti occur on Aruba, Curaçao, and Bonaire. Note the large straight spines, unlike the recurved spines of *M. curvispinus* from Paraguaná.

Klein Curaçao

Klein Curaçao is a coral island situated 9 km southeast of Curaçao. The *Cnemidophorus murinus* here are smaller, have a larger difference in size between the sexes, and the males have brighter blue colors than those on Curaçao. Many tourists visit the island on day trips; one tour operator has a large hut onshore, the other a large roof where the tourists can enjoy some shade. These daytrips usually include a meal of barbecue

An adult male Curaçao Whiptail (*Cnemidophorus murinus*) threatening a rival, which is outside the field of view.

with salad, which is often shared with lizards. One of the operators used to feed the lizards all remaining salad, but he has stopped doing so. Possibly as a consequence of the supplemental food, lizard numbers had been increasing and densities almost certainly exceeded the natural carrying capacity of the island. When one walks around the island, one is struck by the fact that lizards near the tourist facilities are considerably larger and better fed than those in the farther reaches of the islet and that the well-fed males maintain or have especially bright blue colors. This would tend to argue against the hypothesis that bright blue colors arise as a result of poor nutrition or nutritional deficiencies. The well-fed lizards are still markedly smaller than their brethren on Curaçao, which

This lighthouse was built in 1879 after a large hurricane had destroyed the previous lighthouse on the 22/23 September 1877.

Male Curaçao Whiptail (*Cnemidophorus murinus*) from Klein Curaçao with bright aqua-blue coloration, especially on the hindlimbs; compare this picture with the more muted colors of *C. murinus* from Curaçao.

suggests that the size difference is at least in part genetically based. The lizards farther from the tourist shelters are fewer in number, live off the sparse vegetation, and they are not nearly as tame as those near the tourist facilities.

On the night of 22/23 September 1877, the storm surge of a large hurricane swept over Klein Curaçao and the lighthouse was completely destroyed. A new lighthouse was inaugurated on 7 June 1879, slightly to the south of where the original had been, and somewhat more in the middle of the island. In the past, the island had a coral ridge about 7 m high, but this ridge has since been excavated completely during phosphate mining operations. At the time of the hurricane, this ridge still partially existed. Today, Klein Curaçao is approximately 2.4 m above sea level. With sea levels rising in response to global climate change, the island is likely to be inundated completely during some future hurricane, and this could be a threat to the lizard population.

Bonaire

The Bonaire Whiptail (*Cnemidophorus ruthveni*) is slightly smaller and differs in coloration when compared to *C. murinus* on Curaçao. Previously considered a subspecies of *C. murinus* (*C. murinus ruthveni*), Ugueto and Harvey (2010) recently elevated the taxon to full species status. On Bonaire, both the names Kododo and Blausana or Lagadishi are used. The head, front legs, and posterior parts of the body of males are gray and the dots on the head are very distinct. The lower body, hindlegs, and upper tail are khaki-colored, the underside of the tail is blue. Females are brown and the flanks and hindlegs have many faint dots, resulting in a marbled appearance. As with *C. murinus* on Curaçao, these lizards are found practically everywhere.

Male (top) and female (bottom) Bonaire Whiptails (*Cnemidophorus ruthveni*).

Mating pair of Bonaire Whiptails (*Cnemidophorus ruthveni*). Note the marked male-biased sexual size dimorphism.

Agave vivipara is found only on Aruba, Curaçao, and Bonaire.

Brandaris, at 241 m the highest hill in Bonaire, is in the Washington/Slagbaai National Park.

An endangered Yellow-shouldered Amazon (*Amazona barbadensis*) feeding on a Candelabra Cactus (*Cereus repandus*) in Bonaire.

Península de Paraguaná

Looking south from Willemstad on Curaçao on a clear day, one can see Puerto Cumarebo and follow the coastal range west to Coro, and sometimes, even farther west, one can make out the Cerro de Sta. Ana on Paraguaná. On such days, this hill, with an elevation of 844 m, can be seen even more clearly from Banda Abau, the western part of Curaçao. The Cerro de Sta. Ana often can be seen more clearly from Aruba, and the Fila de Montecano, a lower range of hills about 240 m high, to the north of the

Cobalt-blue Blue Lizards (*Cnemidophorus lemniscatus splendidus*) occur in a region called Sisibauco, which lies to the south of the little village of Miraca. The peak in the background, the Cerro de Sta. Ana with an elevation of 844 m, is the major defining landmark of Paraguaná. In clear weather, it can be seen from both Curaçao and Aruba.

Cerro de Sta. Ana is usually visible. I had always wanted to visit Paraguaná, but although I had traveled in Venezuela extensively, had visited Coro twice, and had read a lot about Paraguaná, I had not been there before. In July 2010, an old wish came true and I flew to the Las Piedras International Airport near Punto Fijo in Paraguaná, directly from Curaçao. The flight takes about 35 minutes in a Bandeirante turboprop.

Ameiva bifrontata is found in eastern Colombia, northern Perú, Aruba, and Venezuela (including Isla de Margarita and Los Testigos). Male *A. bifrontata* on Paraguaná have blue coloring on their sides and dark brown dorsal strips; in contrast, the bluish lateral coloration is either absent or almost unnoticeable and the dorsal stripes are poorly developed in *A. bifrontata* from Aruba.

The distribution of *Ameiva ameiva* includes Panamá, most of tropical South America, Trinidad and Tobago, and the St. Vincent and Grenada island banks in the West Indies. *Ameiva ameiva* on Paraguaná occurs in the dry tropical forests of the 16-km^2 Reserva Biológica Montecano, where they differ from those elsewhere — and have provisionally been assigned to *A. a. praesignis*. The status of this subspecies, however, is uncertain (G. Ugueto, pers. comm.), as meristic characteristics have not been studied. Consequently, this population could turn out to be a different subspecies or even a separate species (E. Infante-Rivero, pers. comm.). Large individuals in this area are largely blue (Markezich et al. 1997) and are locally called "Lagarto azul" to distinguish them from the smaller *C. lemniscatus splendidus*, which, among other names, is called "Lagartija azul" (using the diminutive lagartija). Unfortunately, during my visit I did not see these large blue lizards, which provides me with a convenient reason to return.

Scarlet Ibis (*Eudocimus ruber*) flying in to the lagoon in the Quebrada Sabría.

Locals on Paraguaná say that snakes do not like to eat the "Bizurre" or "Visure," which are local names for *Cnemidophorus lemniscatus splendidus,* which is also called "Lagartija azul." While photographing these animals, I was surprised that these blue lizards could be approached much more readily than the yellow-brown-green Rainbow Whiptail Lizards (*C. arenivagus*). The latter, locally called "Lagartija verde," are found in many areas with sandy soil and can be very abundant in the dunes along the coast. In some areas, the two species occur sympatrically, although *C. lemniscatus splendidus* is generally found nearer the center of Paraguaná, often in association with dry tropical forest. In an area near the Fundu or Villa San Francisco, where both species occur, the differences in behavior were especially obvious. Using a 300-mm telephoto lens, I could not get near *C. arenivagus*, which was quite wary, and I did not manage to take any photographs. In sharp contrast,

Melocactus curvispinus is common in Paraguaná. Note the recurved spines reflected by the species' scientific name and compare it with *M. macracanthus,* which is found in Aruba, Curaçao, and Bonaire.

An unusually colored *Cnemidophorus* from the Fundu San Francisco. This individual is quite unlike typical *C. arenivagus* found in that area, nor does it look like *C. lemniscatus splendidus.* Might it be a hybrid?

I could approach *C. lemniscatus splendidus* so closely that I could not focus and had to step back. One would not expect this latter behavior from wild mainland animals. On an island, animals often can be approached quite closely and, generally speaking, the smaller the island, the tamer the animals. This leads me to think that there might be some truth to the contention of some local residents that blue color conveys some form of protection.

A deep cobalt-blue *Cnemidophorus lemniscatus splendidus* from Sisibauco. Note the "paw-waving" behavior peculiar to some species of Whiptail Lizards.

Male (top) and female (bottom) Rainbow Whiptail Lizards (*Cnemidophorus arenivagus*) from the dunes and sandy areas along the coastal road from Adicora to Coro, south of La Bocaina, Paraguaná.

Male (top) and female (bottom) *Ameiva bifrontata* from Camunare, 2 km NNW of Baraived in Paraguaná. Note the ticks on the right shoulder and the bluish color on the sides of the male. In male *A. bifrontata* from Aruba, this bluish color is normally absent or almost unnoticable. Female *A. bifrontata* from Aruba often lack the dark brown stripes and dorsal triangles or they are much less distinctly expressed.

Juvenile Giant Ameiva (*Ameiva ameiva*) from the Fila de Montecano National Park (Reserva Biológica Montecano) in Paraguaná. In Venezuela, these lizards are called Come Huevos (egg eater), Garipiale, Mato común, or Mato real. *Ameiva ameiva* has a large range; it is found from Panama throughout tropical South America including Trinidad and Tobago, Grenada, and St. Vincent. The lizards in Paraguaná are somewhat different from those elsewhere and have provisionally been classified as a subspecies, *A. a. praesignis* (G. Ugueto, pers. comm.), although no formal meristic evaluations have been conducted. The status of this subspecies is thus uncertain, and these lizards could represent a distinct species (E. Infante-Rivero, pers. comm.).

Large locusts called Langoston (*Tropidacris cristata*) are very common in Paraguaná.

Conservation

None of the populations of these lizards are endangered or threatened. Most acclimate quite well to the presence of humans and several populations are protected in established national parks. The most likely future threat would be new invasive species, such as a disease, a competitor, or a predator. The introduction of the Small Indian Mongoose (*Herpestes auropunctatus*), for example, has led to the extirpation or extinction of several ground-dwelling reptiles on West Indian Islands (e.g., Henderson and Powell 2009). In the case of the Klein Curaçao *Cnemidophorus murinus* population, sea level rise is a threat.

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ROATAN VORTEX

The author measuring the snout-vent length of a *Ctenosaura oedirhina* at the Gumbalimba Park and Reserve.

WOMEN IN HERPETOLOGY

On the Iguana Trail

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Photographs by the author except where indicated.

I met my first wild iguana in the spring of 2000. After sailing southeast from Nassau to the Exuma Island chain in the Bahamas, we landed in the midst of the Allen Cays. This was not only my first wild iguana encounter, it was my first time in the Caribbean — and it was breathtaking. I was on a May-term research trip with my undergraduate mentor, John Iverson. Reptiles had always fascinated me, but seeing these iguanas in their natural habitat brought them into a new light. I was immediately enthralled by their behavior and ecstatic about being able to take part in Dr. Iverson's long-term study of the Allen Cays Rock Iguana, *Cyclura cychlura inornata.* Over the course of my undergraduate career, I continued to take part in this iguana study and as many other herpetological projects as possible. These ranged from studying the dynamics of amphibian re-introductions to the dynamics of over-wintering Northern Painted Turtles (*Chrysemys picta*) and the daily activities of the Lesser Antillean endemic *Iguana delicatissima.*

After securing a spot to pursue my doctorate at the University of Tennessee, I took a year off to gain more experience with reptiles around the world. This adventure started with a move to Australia as a visiting fellow at the Australian National University in Canberra. I spent six months there working with Sharon Downes and Scott Keogh on a behavioral study of retreat-site selection in Velvet Geckos (*Oedura lesueurii*). I then traveled to Costa Rica as a biological consultant on a locally driven sea turtle project in Parismina. It was this latter experience that provided my first encounter with the difficulties of being a young female herpetologist. I immediately was told that the local team was surprised (and, in some cases, disappointed) to find out that a young female had come to share information in an effort to revamp the *in situ* egg incubation project that was underway. Despite the difficulties, I forged on and was able to gain some of the group's trust and support. Finishing my time abroad with a little backpacking from Costa Rica to Mexico, I returned to the U.S. to begin work on my Ph.D. dissertation.

My time in Central America exposed me to a new group of iguanas, the ctenosaurs or Spiny-tailed Iguanas (*Ctenosaura* spp.). Apparently, no matter what I did, something always drew me back to iguanas. Thus, under the mentorship of Sandy Echternacht, I developed and implemented a doctoral project in which I evaluated a variety of conservation issues with regard to the *Ctenosaura palearis* clade of Honduras and Guatemala. This clade includes four of the most threatened species within the genus. I used molecular techniques to better understand the species boundaries within this clade, evaluating the threat of hybridization between the island endemic

Marked adult male *Ctenosaura oedirhina* at the Gumbalimba Park and Reserve, Roatán.

Piebald *Ctenosaura oedirhina* at the Gumbalimba Park and Reserve, Roatán.

ROATAN VORTEX

Local field assistant, Mikel Belcaries, and the author with the research vehicle.

C. bakeri and its wide-ranging congener, *C. similis*, and defining evolutionarily significant units for the disjunct populations of *C. melanosterna*.

Throughout my time researching these four species of ctenosaurs, I became increasingly aware of the fact that very little was known about them. In particular, nearly nothing had been done to better understand the basic biology of the island endemic, *C. oedirhina*, which was not formally described until 1987. Thus, throughout the last year of my Ph.D. program, I devoted my spare time to grant writing, in hopes of creating a postdoctoral position for myself to return to Roatán, Honduras and focus on this very understudied, threatened species. Upon completion of my Ph.D. and with funding from USFWS Wildlife Without Borders, Mohamed bin Zayed Species Conservation Fund, the International Iguana Foundation, and the Dutch Iguana Foundation, I moved to Roatán in August 2010 to begin creating a conservation program. This program, in line with my goals as a conservation biologist, was to approach the situation from a holistic perspective, joining research with education and management planning, all the while working closely with the local community.

Ctenosaura oedirhina in the Red Mangrove forest near Jonesville, Roatán.

The Iguanas

Large lizards, such as the iguanas, are among the most endangered species of lizards in the world. This is attributable in part to the fact that many of these species are island endemics. Threats faced by island species often are accentuated, as these forms are restricted to small and often rapidly developing areas, are more prone to extinction from introduced competitors and predators, and are at a higher risk for threats associated with the loss of genetic diversity. Iguanas also are often targets of harvesting for human consumption and the international pet trade.

Among the many reptiles in danger of extinction in Mesoamerica are the Spiny-tailed Iguanas (*Ctenosaura* spp.). Of the 11 genera of iguanid lizards, the genus *Ctenosaura* is the most species-rich, encompassing 18 currently recognized species, or nearly 50% of the known diversity in the family Iguanidae. This understudied genus of iguanas is threatened with extinction primarily due to habitat destruction and over-harvesting, and has not attracted as much publicity or as many conservation efforts as their close relatives, the endangered West Indian Rock Iguanas in the genus *Cyclura*. In most cases, ctenosaurs lack any *active* means of protection at the national and regional levels. Although laws are often in place, enforcement has been sporadic at best. Consequently, illegal poaching usually goes unnoticed. Likewise, in many cases, destruction of prime ctenosaur habitats (e.g., mangrove forests) is prohibited, but proceeds anyway, as habitats are afforded almost no effective protection.

The four species in the *C. palearis* clade (*C. palearis, C. oedirhina, C. bakeri*, and *C. melanosterna*) are included in the IUCN Red List of Threatened and Endangered Species. They are endemic to the Bay Islands and northern versant of Honduras, and the Valle de Motagua, Guatemala. This clade encompasses the most threatened species within the genus and exemplifies the family-wide decline associated with a particular vulnerability due to their narrow ranges. To combat a more recent threat, in a joint effort between Daniel Ariano of the Guatemalan NGO Zootropic, myself, and the Guatemalan and Honduran governments, we succeeded in the inclusion of all four of these species in CITES Appendix II. This is a great step forward for conservation of these species on the international level, but does not address many of the national and regional issues that must be considered in order to protect these animals. Despite a current lack of information concerning the basic biology of these species, evidence strongly suggests that all four species are in decline and at high risk of extinction. The 2008 IUCN Iguana Specialists Group (ISG) meeting and workshop

on Utila identified research objectives necessary to protect and conserve *C. melanosterna*, *C. bakeri*, and *C. palearis*. Unfortunately, concerns regarding *C. oedirhina* could not be addressed due to a lack of basic information.

Roatán's Spiny-tailed Iguanas (*Ctenosaura oedirhina*) are endemic to the small (156 km^2) and rapidly developing island of Roatán, located 48 km north of the Caribbean versant of Honduras. This species is listed as Endangered on the IUCN Red List (www.iucnredlist.org/apps/redlist/details/44191/0) due to its limited and fragmented geographic range, small population size, and imminent threats posed by habitat destruction and the pet trade. More recently, a new threat has become apparent. A wide-ranging congener, *C. similis*, has been introduced to a small island just off Roatán. Since *C. similis* could easily navigate the narrow canal between this satellite island and Roatán itself, this introduction has the potential to devastate the *C. oedirhina* population through competition and/or hybridization with the introduced species. *Ctenosaura similis* is known to hybridize with *C. bakeri*, the sister taxon of *C. oedirhina*. Consequently, the same threat is almost certainly applicable to *C. oedirhina*. To combat the potential extinction of this species, I formulated a multi-faceted approach, focusing on local capacity building, education, habitat protection, and population monitoring.

In a situation such as this, where no active legislation protects the species, no local awareness concerning the status of the species exists, and hunting is the greatest threat, education and grass-roots initiatives are the key to sustainable conservation measures. The situation is made even more difficult by the fact that little is known about the biology of these lizards. Thus, in order to commence an education program, basic biological data need to be collected simultaneously. Although complex, this situation provides an opportunity for me to involve local individuals in all aspects of the project, enhancing the likelihood that they will develop a sense of ownership and pride in the project and any subsequent conservation measures, and that this desire will facilitate the continuation of the project into the future.

I currently am working with local individuals to collect life history data concerning morphometrics, diet, reproduction, population size, and extent of occurrence. Local involvement not only aids in the collection of these data, but also allows the community to feel comfortable asking questions and then sharing the information. Thus far, we have made some exciting discoveries. For example, we have identified what appears to be an ontogenetic shift toward piebaldism and an ability for limb regeneration, neither of which have ever been documented in iguanas. I also am working to create awareness among local tour guides, so that they may disseminate information to tourists who often are offered iguana meat, with property owners in developing grass-roots conservation actions for their respective properties, and with schools interested in adding a conservation component into their curricula. In addition, we have started holding a series of workshops, where representatives from local organizations and stakeholders throughout the region get together to discuss conservation issues in general and how they relate to the protection of Roatán's endemic iguanas. These meetings have been hugely beneficial not only to my project goals but in bringing these individuals together to form collaborations for the betterment of the entire biota of the region.

Ctenosaura oedirhina in a Black Mangrove at a permanent study site, Coco View Resort, Roatán.

MIKEL BELCARIES

The author (far left) training tour guides about *Ctenosaura oedirhina* at one of her study sites, Gumbalimba Park and Reserve, Roatán.

As with any career, one faces difficulties. These challenges, however, cause one to become stronger and more driven. Although herpetology has traditionally been male-biased, I feel that the difficulties for a woman are essentially the same problems women face in the sciences in general. Being taken seriously has been the greatest struggle for me, particularly while in the field catching and handling animals. However, a positive side becomes evident once people observe these field methods a few times; they often are eager to become involved, and are frequently less intimidated when approaching me than they might be with a man. On many occasions, I have been preparing to catch an iguana when a local man steps forward to warn me about the dangers of attempting such a task. However, after seeing me complete the capture without incurring any harm, they are eager to discuss the situation and become engaged. In addition, women and children often feel particularly comfortable approaching me and asking to take part in the studies. I feel that it is important for people to witness women in roles in which they normally see men. The demography of many disciplines is constantly changing, and the most important thing a female herpetologist — or scientist of any kind — can do is support and encourage others. The field of herpetology (like all sciences) and the unique and wonderful creatures that need our protection will benefit from the multiple perspectives of more diverse advocates.

Juvenile Stout Iguanas (*Cyclura pinguis*) spend much of their time in trees. This individual (marked #12) was taking an afternoon nap in a White Cedar (*Tabebuia heterophylla*). It was not disturbed while this photograph was taken.

TRAVELOGUE

What Stout Iguanas (Don't) Do All Day

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Photographs by the author except where indicated.

While some 16-year-olds are busy debating the meaning of life or determining their purpose in the world, I spent a week doing field research in the British Virgin Islands (BVI). Guana Island, where the work was conducted, is a private island. It is home to at least 50 species of birds, five species of bats, more than 14 species of reptiles and amphibians, and hundreds of plant and insect species (Lazell, 2005). I have visited the island a few times in the past and had the chance to assist with a bird study last fall.

This past October, I designed and executed my own behavioral study on juvenile Stout Iguanas. *Cyclura pinguis*, commonly referred to as the Stout Iguana or Anegada Ground Iguana, is a critically endangered lizard that can be found only in the BVI. Eight individuals were moved to Guana Island in the 1980s in an effort to protect the species, whose one remaining population on Anegada was declining. I would be responsible for observing a critically endangered species, of which only a few hundred exist, but also be one of the lucky few to get the chance to study them. While writing up my project proposal, I grew more and more excited, dreaming up incredible scenarios of never-before-seen iguana interactions.

I set out to do a basic behavioral study on juveniles, as few had been done. I would be looking for time spent on the ground, time spent in trees, time spent sunning, what and when they were eating, and more. In my procedure, I assumed that once I arrived on the island, the iguanas would basically come flocking to my feet, begging me to study them. I had planned to radio-track five iguanas, hoping I would find three in one location and two in another. This way I would experience interactions between them, as well as see whether or not their behavior changed depending on the habitat in different locations. Unfortunately, finding five iguanas proved to be quite a challenge. They were present in abundance at the beginning of October, but by the time I arrived on Guana in late October, most of them had suddenly disappeared (perhaps because they knew a reckless adolescent was coming). However, two were found near the dining area and transmitters

Guana Island, home to all the juvenile *Cyclura pinguis* in this investigation.

GAD PERRY

The author using telemetry equipment to find one of the juvenile *Cyclura pinguis* in a Mango Tree (*Mangifera indica*) in the late afternoon.

were attached. Three more were found in the orchard, and so I had all five iguanas ready to go, thanks to the scientists already there. I now needed to learn how to use the equipment to track them, which proved to be another challenge. The receiver made beeping sounds I was supposed to interpret. Even during practice, while finding immobile transmitters, I picked up wrong signals, went in the opposite direction of the signal, or simply turned around in circles until I became dizzy. Nonetheless, by the end of the week, I had "mastered" the tracking equipment.

Being the unlucky teenager I am, a juvenile iguana died the first morning I was on the island. I followed a signal all the way to a pool behind one of the guesthouses. After looking around on the edge and in the surrounding bushes, I finally discovered the baby at the bottom of the pool. It had drowned. Although the death of the lizard had nothing to do with the study, I felt like a murderer. Not only that, but via Facebook — what else? — word got around my high school back home that I had chased a baby iguana into a pool and held it under water until it died. This was social suicide at its finest.

In the bio lab courses at my high school, the experiments are for the most part already set up, with clear instructions that, when carefully followed, earn an almost automatic A. On Guana, although I had to write the procedure myself, as long as I followed it exactly as written, I was *bound* to be successful, right? Boy, was I wrong! After the death of the iguana, I put my sadness and confusion aside, picked up the signal of my second iguana, and tracked it to a Spider Lily. I sat next to the Spider Lily, staring at it, for three hours. I recorded every rustle, movement, and bird overhead for three hours, then decided to recheck the signal and make sure it was still in the plant. Lo and behold, the signal was now coming from somewhere entirely different. I had sat staring at a plant, sweat pouring out of me, for *three hours*, and to no avail. I packed up my gear and followed the signal to the actual location of the iguana. When I spotted it sitting on a branch in a tree a ways off the path, my heart rejoiced. I had found my iguana, and it was alive! I then commenced my note-taking once again, writing down every movement, occurrence, sound, anything. By the end of the week I

Juvenile #19 basking in the afternoon sun.

Juvenile #12 doing "push-ups" around midday.

Juvenile #22 on the ground munching a vegetarian meal.

GAD PERRY

The author marking an iguana with Wite-out®.

discovered that juvenile Stout Iguanas do not do much. Even so, I kept myself busy writing down anything and everything that occurred.

The next day, we found a new iguana and attached a transmitter. All I could hope was that this juvenile survived, despite the cursed transmitter on its back. Further complications arose when one of the three iguanas from the orchard was released in the wrong location. This was the second detour from my thoroughly thought-out procedure. Why wasn't everything going as planned? I wanted an "A" on this lab! After trying and not succeeding in finding the misplaced iguana, I decided to make a little experiment out of the situation — I would see whether the iguana made it back to the orchard by the time I left. I figured, if nature was changing my experiment's course, so could I. I further amended my experiment, not only taking down behavioral observations but also taking a picture of the iguanas and of their surroundings every half hour. I would then determine the amount of sun exposure the iguanas had in their current location and the amount of sunlight available in their current environment.

I spent all of that second day watching the iguana near the dining area. I found it sitting in the exact location where I had left it the evening before. By the third day, I got into the rhythm of things — eating breakfast, sitting and watching iguanas for hours, eating lunch, sitting and watching iguanas for hours, eating dinner, checking location of iguanas, sleeping (with occasional nightmares of iguanas drowning). I had not expected this little excitement and movement to cause such exhaustion. That morning, I watched the iguana near the dining area until it began to rain and the lizard took cover. I headed to the orchard and, to my surprise, found one of the two lizards roaming around on the ground. Apparently, what I had laid out in my procedure was finally occurring. The iguana moved around on the ground almost all of that morning. While nibbling on some plants, it suddenly lurched toward me. A few seconds later, a snake (a Puerto Rican Racer, *Borikenophis portoricensis*) came out of a nearby bush, stopped, then continued on. My heart nearly jumped out of my chest, as I stood there with my baby at my feet. I began to imagine scenarios of the snake whipping its head around and attacking the juvenile. Part of me wanted to save the baby iguana if that were to happen, but another part of me shouted: "No! The baby must die because nature wills it!" Luckily I did not have to make that decision — the snake slithered off and never came back. I later found out that it was too small to have even considered eating the baby. When I came back in the afternoon, the juvenile was sitting in a tree. Patterns began to develop as I found that the juveniles usually roam, forage, and eat in the mornings, with activity peaking around 9 or 10 AM. They then retreat to higher, safer locations in the afternoon. More often than not, the location they were in around 3 PM was where I would find them the next morning.

The lizards often head-bobbed as soon as they became aware of my presence, as well as when other lizards were nearby. On the fourth day, both of the iguanas in the orchard were on the ground foraging. Although they were not close to one another, I stood between them hoping for some interaction. Naturally, nothing happened, but I still found them eating the same plants and climbing the same trees. In fact, when the iguanas were sitting in trees, they were always found in White Cedars (*Tabebuia heterophylla*). By the fifth day, one of the iguanas had shed its transmitter under a Mango Tree (*Mangifera indica*). I watched the one iguana left in the orchard for the rest of the morning, with foraging occurring around 10 AM, as every other morning. In the afternoon, I began to search for the mis-released iguana that belonged in the orchard. The signal was still coming from the general area of where it was released, although it had moved in the direction of the orchard. On the sixth day, I watched the lone orchard iguana yet again. After tracking the mis-released juvenile, I discovered it had made great headway in moving toward the orchard. It had moved 79 m closer after just a few days. It did the same again on the next day, moving another 71

Map of Guana Island showing movements of the iguana mistakenly released at a site other than where it was originally caught. "1" marks where the iguana was caught, and "2" where it was later released.

m toward the orchard. A few days after I left Guana, however, the iguana moved 54 m back toward the location where it had been released and away from where I first found it in the orchard.

On my last day on the island, I needed to catch all my iguanas and take the transmitters off. After an iguana was caught, I got a chance to hold it. As most transmitters had been put on before I got to the island, this was the first time I was able to hold one. My attachment to the little guys grew, as I finally got to experience what they felt like, see their faces up close, and marvel at the beauty of their coloration. Once the transmitter was removed, each iguana scampered off, and that was the last I saw of it.

When I got back home to freezing cold New Jersey, not only did I miss the warmth of Guana Island, but I also found myself longing to track the life of my newfound friends. I wanted to know what they were doing, where they were sleeping, whether they were still alive or not. I took stock of what I had learned. I found that juvenile *Cyclura pinguis* spend most of their time in trees. I observed them on the ground for an average of three hours a day, almost invariably in the morning, but found them in trees the rest of the time. Although I did not observe them for 24-hour periods, they apparently spend almost 90% of their time in trees. Not only do they spend a good amount of their day in trees, they were relatively high as well. On average, the iguanas were 5.5 m above the ground, although they occasionally were so high I was unable to see them at all. Being high in trees presumably offers juveniles added protection; they are well camouflaged in the foliage. Previous reports indicate that they are eaten by American Kestrels (*Falco sparvarius*) and snakes, both of which are common. Although I had hypothesized that the juveniles were actively seeking to maximize their sun exposure, I found that this was not necessarily the case. On average, 57 ± 24% of the iguana was exposed to sunlight, compared to 60 ± 17% of their environment. The difference between insolation at and away from iguana locations was not significant (Wilcoxon Signed Ranks Test; Z = 0.87, P = 0.39). Consequently, I concluded that the lizards do not appear to be choosing perches based on available sunlight. As the experimental group was relatively small (only 23 data pairs were tested) and the camera settings might have varied between photographs, these numbers should be considered preliminary data in need of further verification.

During my observations, lizards fed mainly on grasses and other vegetation on the ground, often small ground plants such as those in the genus *Ruellia*. Nonetheless, I occasionally spotted them eating leaves of trees in which they perched, and I cannot rule out the possibility that they feed on an occasional insect. I realized that other than eat and bask, the juveniles essentially did not do much. I also realized that these Stout Iguanas would not be critically endangered if everyone had the chance to follow them around for just a day. Their manners, their beauty, simply put, everything about them is fascinating. They need to be conserved for generations to come.

I also learned a lot about field research. Having done field research in the past, I am surprised time and time again by how much more I am able to learn doing hands-on work versus sitting in a classroom. Not only this, but I have finally learned how unpredictable working in nature is. Although high school experiments do serve an educational purpose, they dramatically misrepresent field research. The procedures provided in textbooks assist in organizing your thoughts, but such guidelines cannot anticipate every

KRISTA MOUGEY

The author holding one of the juvenile iguanas at the end of the project. Once the transmitter was removed, the iguana scampered off, and that was the last we saw of it.

Once Stout Iguanas are fully mature, their cuteness is replaced by a regal air.

eventuality. When Nature presents the unexpected, true researchers must quickly adapt to the situation for the good of the investigation. While the mis-releasing of one of the iguanas was an unforeseen accident, I ended up observing its attempt to return home, something nobody had previously reported.

Having to detour from my pre-determined procedures, although scary, emphasized the realization that nature is unpredictable. Although I am certainly no expert — yet, I was forced to practice making the necessary adjustments on several occasions during my week on Guana Island. I began to appreciate the times when my experiment did go as planned. I found indescribable joy in discovering my iguanas within a few minutes, rather than a few hours or not at all. Although the experiments in the high school lab will continue, I can now appreciate the amount of effort, energy, and reworking of procedures necessary for conducting most scientific investigations.

Finally, I learned a lot about myself (including that being tall is not necessarily an advantage when bushwhacking through dense vegetation). It was incredibly tedious to concentrate on one small, fluorescent green object for hours on end. In school, classes are only 50 minutes long, meaning I concentrate on a given topic for a maximum of 40 minutes (depending on the subject). These fairly stationary lizards taught me patience and extreme concentration. Not only that, but I am fairly certain my eyesight improved while on the island, seeing as I needed to strain my eyes more than I ever have before, trying to discover a green blob clutching a leafy, green tree. I am in awe of those who dedicate their life to this kind of work. However tedious the effort, the brief moments of movement provided me with a day's worth of excitement and gaiety. I grew attached to my juveniles, memorizing their transmitter numbers, and speaking of them as if they were my own. I had debated giving the iguanas names before beginning, to help me differentiate between them, but in retrospect I am glad I did not, otherwise the separation would have been unbearable.

Having this opportunity to work with critically endangered iguanas is one I will never forget. I cannot thank Dr. Henry and Gloria Jarecki enough for their interest in my project and for their vision to preserve the wildlife and natural beauty of this magical island. Guana would not be what it is today without their constant work and effort in caring for it. I also am deeply indebted to Drs. James "Skip" Lazell and Gad Perry for sharing their knowledge, being so generous with their time, showing infinite patience, providing constant encouragement, and a refreshing sense of humor — in short, being amazing mentors. I learned so much from them. My experience with telemetry equipment, discovery of iguanas, tagging of iguanas, and overall lack of insanity in the hours spent in the heat would be nothing without Krista Mougey. Special thanks to Renée Rondeau, whose unmatched plant knowledge proved to be indispensable when looking at multiple images of green, leafy specimens. I will be forever grateful for this opportunity that has further fueled my passion for biology, and I cannot wait until I get a chance to do field research again. Which is why I part with these words: "Beware iguanas. Katharina will be back."

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A Chuckwalla (*Sauromalus ater*) in the Valley of Fire.

TRAVELOGUE

Beyond the Valley of Fire

Tim Spuckler

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Photographs by the author.

A little-visited area rich in natural history, folklore, and rock formations reveals that taking the "road less traveled" is sometimes worth the trip.

About a half-hour outside Las Vegas is Valley of Fire State Park. The name refers to the spectacular red sandstone formations that are found in particular abundance there. Although I've done the "tourist" part of the park several times, driving the paved road and marveling at the landscape, today was going to be a different type of trip. We were set to visit Valley of Fire by going via the back roads. Our hope was to get a taste of Vegas from the days of old by seeing Native American petroglyphs and visiting remnants of places where prospectors once lived. We also hoped to see additional rock formations that cannot be viewed from the main road going through the park. These geological wonders include Buffington Pockets, Color Rock Quarry, and Opal Fields — all under the shadow of the Muddy Mountains.

The Bureau of Land Management's Bitter Springs Backcountry Byway gives visitors access to the Muddy Mountains Wilderness and the Buffington Pockets area. Before entering the byway, we stocked up on homemade beef jerky from a roadside stand outside the Moapa Indian Reservation store at the entrance of the park. About three miles later, the paved road bends left, but we followed the trail straight to the mountains. A BLM sign informed us that we had reached the Bitter Springs Backcountry Byway.

Although the dirt road starts out fairly smooth, eventually a high-clearance vehicle, preferably with four-wheel drive, is required. The road becomes bumpy and rock-filled. Some of the rocks are surprisingly sharp, so we were grateful we had new tires and a readily accessible spare. Being a passenger in a truck during the difficult drive is a bone-rattling experience, but the view is nice. We drove past yellow and red sandstone formations that are similar to the magnificent rocks seen in the Valley of Fire. The formations are known as the Buffington Pockets, natural basins that trap rainwater. These beautiful outcroppings, tinted by iron ore and other minerals, are a startling contrast to the limestone hills of the Muddy Mountains. Scrambling across and along the edges of the road were Desert Horned

The spectacular red sandstone formations for which the Valley of Fire is named.

Scrambling across and along the edges of the road were Desert Horned Lizards (*Phrynosoma platyrhinos*), their formidable, dinosaur-like appearance quite a contrast to their mild disposition.

Lizards (*Phrynosoma platyrhinos*), their formidable, dinosaur-like appearance quite a contrast to their mild disposition.

In the early 1920s, a cattle rancher named Warren Buffington wandered onto this location and noticed the burnt oranges and reds of the sandstone. A spring flowing from a narrow, twisting canyon completed the idea that the spot might be a "hidden paradise" in the harsh desert. We noticed the large cement wall that Buffington built at the head of the canyon to retain water for year-round use. The remnants of his cabin were just beyond the wall. The scene was worthy of further investigation.

A large cement wall built by a cattle rancher named Warren Buffington in the early 1920s at the head of the canyon to retain water for year-round use.

Petroglyphs are Native American rock engravings created by removing part of a rock surface by incising, pecking, carving, and abrading it. Some of the graphics resemble bighorn sheep, some resemble people, and one even looks very much like a rattlesnake.

As we approached the remains of the old house, we noticed puddles of water in the rock. Closer observation revealed that these small basins contain *Triops cancriformis*, a living fossil that has not changed in appearance since the Triassic Period. Although I had heard of these prehistoric-looking

creatures, these were the first I had seen. Often called "Tadpole Shrimp," a shield-like carapace and a fused pair of tiny eyes made me think of a miniature Horseshoe Crab. Not only are they fascinating in appearance, but the lifestyle of these crustaceans is equally interesting. Adults usually live only a few days — enough time to lay eggs before their pool of water evaporates. The eggs survive in the dry conditions under the hot sun for periods up to several years, until rains come and refill the basin where they rest. Then the whole process starts over again. We spent quite a bit of time observing the desert crustaceans and pondering the unlikelihood of a creature dependent on standing water making a living in the harsh, dry desert.

Small basins contain *Triops cancriformis*, a living fossil that has not changed in appearance since the Triassic Period. Although I had heard of these prehistoric-looking creatures, these were the first I had seen. Often called "Tadpole Shrimp," a shield-like carapace and a fused pair of tiny eyes made me think of a miniature Horseshoe Crab.

Western Coachwhip (*Masticophis flagellum testaceus*). Sometimes called a "Red Racer," this is the fastest snake in the land, although the individual we found seemed cool, content, and secure in its deep rock lair.

Side-blotched Lizard (*Uta stansburiana*).

Our thoughts were interrupted by a decent-sized reptile sprinting past on its hindlimbs. "Did you see that?" "What the heck was it?" We headed to where we had seen the lizard disappear. After some concentrated searching, we found a Mojave Collared Lizard (*Crotaphytus bicinctores*) among the rocks. Big-headed and with strong back legs, we drew comparisons to a tiny "T-rex." Our heads now filled with these prehistoric images, we glanced up from where the Collared Lizard had led us to see the rock walls covered with petroglyphs — rock engravings created by removing part of a rock surface by incising, pecking, carving, and abrading it. Some of the graphics resemble bighorn sheep, some resemble people, and one even looks very much like a rattlesnake. It was a bit spooky and more than a little fascinating to view these ancient etchings.

Although not as common here as in other parts of the desert, Side-blotched Lizards (*Uta stansburiana*) are seen from time to time, either basking or scrambling over rocks near the petroglyphs. These lizards are often approachable, and therefore easily photographed. They don't seem to mind going about their business if humans are nearby, so we seized the opportunity to see them hunt, do "push ups," and chase each other around. Albeit small (about 10 cm in total length), males can be quite colorful. While peering into a deep rock crevice, one of us spotted the first snake of the day, a Western Coachwhip (*Masticophis flagellum testaceus*). Sometimes called a "Red Racer," this is the fastest snake in the land, although the individual we found seemed cool, content, and secure in its deep rock lair. We took photos and, as we finished, a sound from above us grabbed our attention. Taking a

Mojave Collared Lizard (*Crotaphytus bicinctores*).

few steps back from the rocky area, we could see what was lurking on top of the rocks — a Chuckwalla (*Sauromalus ater*). The large, bulky herbivorous lizard seemed just as curious about us as we were about it.

Eventually we made our way back to the wall and the spring that runs near it. Although not much water was flowing on that day in early June, the ground around the spring is damp enough to support vegetation, like Desert Sage (*Salvia dorrii*) and Squawbush (*Rhus aromatica*). Perhaps these grew naturally or maybe Mr. Buffington planted their ancestors for their medicinal qualities and as a food source, respectively. Searching the shoreline turned up one of the most commonly seen desert amphibians, the Red-spotted Toad (*Anaxyrus punctatus*). This small toad has round parotid glands, a characteristic that distinguishes it from other species of toads in the region. Its scattered red bumps are another distinguishing marking, although the coloration of this amphibian is rather variable. The example we found certainly lived up to its name, adorned as it was with many bright red dots. The damp conditions also provide a favorable microhabitat for one of the largest arachnids in the United States, the Desert Hairy Scorpion (*Hadrurus arizonensis*). These impressive invertebrates often can be found in substantial numbers in desert areas that retain humidity.

Red-spotted Toad (*Anaxyrus punctatus*).

While investigating an *Agave* pit, we encountered another common saurian. When disturbed, the Western Whiptail (*Aspidoscelis tigris*) characteristically runs several yards before stopping to look back at the source of its disturbance. Sometimes these lizards appear oblivious to humans keeping a distance of 5–6 m, and on these occasions their foraging, territorial, and courtship behaviors can be observed. We commented on the lizards and then turned our attention back to the pit. *Agave* is a type of yucca plant that was used as food for thousands of years by Native Americans. *Agave* was harvested and the sweet-tasting hearts were roasted in large pits during communal gatherings. Plants were placed in a bed of hot coals mixed with limestone cobbles and covered with vegetable material and sometimes earth. An *Agave* pit was a place to gather and feast, prepare for the winter, and meet for dancing and religious ceremonies.

At about three-quarters of the way through the nearly 30 km (~18 mi) of back roads, we decided to check out some rocky and scenic habitat. It would be our last stop before ending our unconventional three-hour adventure. The temperature was becoming quite warm and we were encountering more and more desert speedsters — Zebratail Lizards (*Callisaurus*

Western Whiptail (*Aspidoscelis tigris*).

Zebratail Lizards (*Callisaurus draconoides*).

draconoides). They have a habit of curling their tails over their backs, thus revealing the striped underside. Hiking around a boulder-strewn, sparsely vegetated open area, I spotted a loosely coiled snake, apparently resting after consuming a sizeable meal. Although I had found the area's two other commonly encountered rattlesnakes, the Sidewinder (*Crotalus cerastes cerastes*) and the Mojave Rattlesnake (*Crotalus scutulatus*), this was the first Speckled Rattlesnake (*Crotalus mitchellii*) I'd ever seen. The sandy pink ground color and hazy darker crossbands worked well to camouflage the motionless snake among dried grass and rocks. It was the largest and most impressive reptile we'd seen during the trip.

We had taken the proverbial "road less traveled," and had come away with an experience richer than driving the paved road through the Valley of Fire. Although rugged and at times quite bumpy, getting a glimpse into the past and seeing a fair amount of local fauna made for a memorable experience.

Speckled Rattlesnake (*Crotalus mitchellii*).

HISTORICAL PERSPECTIVE

An Account of the Rattlesnake[1]

By the Honourable Paul Dudley, *Esq*; *F.R.S.*

The Rattlesnake is reckoned by the *Ab-origines*, to be the most terrible of all Snakes, and the Master of the Serpent-kind; that which causes their Terror, without doubt, is their mortal Venom, and the Ensign of it is their Rattle; and it is most certain, that both Men and Beasts are more afraid of them, than of other Snakes; and while the common Snake avoids a Man, this will never turn out of the Way.

There are three Sorts, or Kinds, of this Snake, and distinguished by their Colour, *viz.* a yellowish Green, a deep Ash Colour, and a black Sattin.

The Eye of this Creature has something so singular and terrible, that there is no looking stedfastly on him; one is apt, almost, to think they are possest by some Demon.

A Rattlesnake creeps with his Head close to the Ground, and is very slow in moving, so that a Man may easily get out of his Way: This ought to be remarked as an Instance of the Goodness of God, who preserves Man and Beast. His leaping and jumping to do Mischief, is no more than extending, or uncoiling himself; for they don't remove their whole Body, as other Creatures do, when they leap; so that a Man is in no Danger of them, if his Distance be more than their Length; neither can they do any Harm when they are in their ordinary Motion, until they first coil and then extend, or uncoil themselves, but they both are done in a Moment's Time.

When a Rattlesnake rests, or sleeps, he is coiled, and they are observed to be exceeding sleepy.

Our People at first took the Noise this Creature makes, to be owing to some little Bones, or hard loose Kernels lodged in their Tails; but soon discovered their Mistake, and found the Tail to be compos'd of Joints, that lap over one another, somewhat like a Lobster's tail; and the striking them one upon another, forms that Noise, which is so terrible to Man and Beast. The fiercest Noise is observ'd to be in clear fair Weather, for when 'tis rainy, they make none at all; for which Reason, the *Indians* don't care to travel in the Woods, in a Time of Rain, for fear of being among these Snakes before they are aware. One other Circumstance of their rattling has been observ'd, to wit, that if a single Snake be surprized and rattles, and there happen to be others near him, they all take the Alarm, and rattle in like manner.

I dare not answer for the Truth of every Story I have heard, of their charming, or Power of Fascination; but yet I am abundantly satisfied from many Witnesses, both *English* and *Indian*, that a Rattlesnake will charm both Squirrels and Birds from a Tree into his Mouth. A Man of undoubted Probity sometime since told me, that as he was in the Woods, he observ'd a Squirrel in great Distress, dancing from one Bough to another, and making a lamentable Noise, till at last he came down the Tree, and ran behind a

[1] Reprinted from the *Philosophical Transactions of the Royal Society*, Vol. 32 (1722–1723), pp. 292–295. Note that we have updated the font, but spelling, punctuation, and italics are as in the original.

TOM TYNING

Dudley described three color phases, this individual is "black Sattin," a pattern rarely seen in populations other than in the northeastern United States.

TOM TYNING

This snake is what Dudley described as "a deep Ash Colour"; the third color phase ("a yellowish Green") is quite rare today, Tom Tyning, who studies Timber Rattlesnakes in Massachusetts, has heard of only two examples in the past 30 years.

Log: The Person going to see what was become of him, spied a great Snake, that had swallow'd him.

And I am the rather confirmed in the Relation, because my own Brother, being in the Woods, opened one of these Snakes, and found two strip'd Squirrels in his belly, and both of them Head foremost. When they charm, they make a hoarse Noise with their Mouths, and a soft Rattle with their Tails, the Eye at the same time fixed on the Prey.

Their general Food consists of Toads, Frogs, Crickets, Grasshoppers, and other Insects, but principally of Ground Mice; and the Rattlesnake again serves for Food to Bears, and even our Hogs will eat them without Harm.

They are viviparous, and bring forth generally about twelve, and in the Month of *June*. A Friend of mine in the Country, being desirous to discover the Nature and Manner of the Generation of the Rattlesnake, gave me the following Account, *viz*. About the middle of *May*, the Time when the Rattlesnakes fist come abroad, he took and opened one of them, and in the *Matrix* found twelve small Globes, as big as a common Marble, in Colour like the Yolk of an Egg; in three or four Days more, he took and opened another, and then plainly perceived a white Speck in the Centre of the yellow Globe; in three or four Days more, he dissected a third, and discovered the Head of a Snake; and in a few Days after that, three Quarters of a Snake was formed, and lying round in a Coil. In the latter End of *June*, he kill'd an old one, and took out perfect live Snakes of six Inches long. In *September*, when the old ones take their Young in, and carry them to their Dens, they are not quite a Foot long. They couple in *August*, and are then most dangerous.

I cannot say, what other Serpents, or poysonous Creatures, may do, but I am satisfied the Rattlesnake does not traject his Poyson; and that unless the Skin be first broke, or an Incision made with his Teeth, his Venom can do no Harm; for my Friend assured me, that he had made an Experiment of it in this manner: He took the Breech of his Gun, and set it upon four or five of them, and after they had bit it, and left several Drops of their Poyson, he with his Hand wiped it off without any Harm.

Our People have several Remedies for the Sting of a Rattlesnake; among other, that which is much made use of, is a Root they call Blood-root, I suppose so named, from the Colour of the Root, and the Juice, which is red like Blood. It grows in great Abundance in our Woods; they bruise the Root, and bind it above the Place that is bit, to prevent the Poison's going farther, at the same Time scarifying the Place affected; some of the Root is also boiled, and the Person poisoned drinks the Water.

They are generally from three to five Feet long, and do not commonly exceed twenty Rattles; and yet I have it attested by a Man of Credit, that he killed a Rattlesnake, some Years since, that had between seventy and eighty Rattles, with a sprinkling of grey Hairs, like Bristles, over his Body; he was full five Foot and an half long, and as big as the Calf of a Man's Leg.

They shed, or throw off their Skins every Year, sometime in the Month of *June*, and turn it inside out when they throw it off. It has also been observed, that the Skin covers not only the Body, but the Head and Eyes.

They generally den among the Rocks in great Numbers together; the Time of their retiring is about the middle of *September*, and they don't come abroad till the middle of *May*, when our Hunters watch them, as they come out a sunning, and kill them by hundreds.

Roxbury, New-England
Octob. 25. 1722.
Paul Dudley

Editor's Remarks

The historical piece reprinted in this issue is one of the oldest we have included, originating in "New-England" in 1722. The author was the grandson of one of the first Governors of the Massachusetts Colony, the son of the Governor of Massachusetts Bay. If the *Proceedings of the Massachusetts Historical Society* are to be trusted, Dudley was admitted to Harvard College at the age of 11. He received his Master's degree in 1693, when he was 18. He went back to England, studied law, and came back to serve on the provincial superior court until his death, including a stint as Chief Justice from 1745–1751. The F.R.S. after the name stands for "Fellow of the Royal Society" (London), and as such he published quite a few papers in the *Philosophical Transactions of the Royal Society*, including "An Account of the Method of Making Sugar from the Juice of the Maple Tree in New England" and "A Description of the Moose-Deer in America."

Science has changed since Dudley's account was published. No modern biologist would suggest that their study organism is so "singular and terrible, that … one is apt, almost, to think they are possest by some Demon." Nor is one likely to view as an "Instance of the Goodness of God" that the snake is slow-moving and "a Man may easily get out of his Way." The article includes some basic biology, much of it second-hand, and additional ethnographical information obtained from "the Indians." Dudley was quite credulous by today's standards. "I am abundantly satisfied from many Witnesses, both English and Indian, that a Rattlesnake will charm both Squirrels and Birds from a Tree into his Mouth." Interestingly, I heard an almost identical tale told in Costa Rica not that long ago, about boas. If you happen to be caught in this spell — apparently it works in people, too — please remember that passing a metal implement between the snake and the victim will break the trance (in Central America, machetes seem to be the preferred implement). However, some things do not change. In Dudley's time, "our Hunters watch [rattlesnakes], as they come out a sunning, and kill them by hundreds." Almost three hundred years later, springtime rattlesnake roundups still involve the slaughter of thousands of snakes, although evidence of negative effects on populations remains elusive and anecdotal.

Gad Perry

CONSERVATION RESEARCH REPORTS

Do Breeding Facilities for Chelonians Threaten Their Stability in the Wild?

The Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) postulates that trade should not imperil the survival of a species in the wild. CITES defines breeding categories as "captive bred," "captive born" or "farmed," and "captive raised" or "ranched." **VINKE AND VINKE** (2009. *Schildkröten im Fokus* 6(4):3–21; 2010 English translation in *Schildkröten im Fokus online* 1:1–18 <www.schildkroeten-im-fokus.de/pdf/2010tradestudy.pdf>) presented and evaluated import and export statistics for different species and countries. Those data were frequently incorrect and inconsistent. In some instances chelonians were misidentified, or they entered a country as "wild caught" and left as "captive bred." The authors addressed the limitations of CITES and suggested means by which importing nations could enhance the conservation status of many species (i.e., by confirming non-detrimental findings emanating in the nation from which animals were exported, such as contentions that animals were not removed from nature). This is mandatory for any importation of listed species into the European Union, but non-detriment studies are lacking for many exporting nations. Because banning trade in a given species might take years to implement, even when an exporting country brazenly breaches the rules, requirements for international trade in live turtles and tortoises should include complete data on all stock movements, individual marking and documentation of breeders, and a requirement for disclosure of all pertinent data before any permit for export or import of "captive-bred" animals is issued. If the current mechanisms of exploitation tolerated under the cover of CITES are not stopped, the threat posed to chelonian species in the wild by the international live animal trade is on a par with that of habitat destruction.

MEL J. RIVERA RODRÍGUEZ

Turtles hatched at breeding farms have often not been "farm-bred," despite claims to the contrary. This fortunate hatchling Red-footed Tortoise (*Chelonoidis carbonaria*) was bred in semi-captivity for conservation purposes and released into the wild.

Using Natural History Collections to Understand Effects of Climate Change

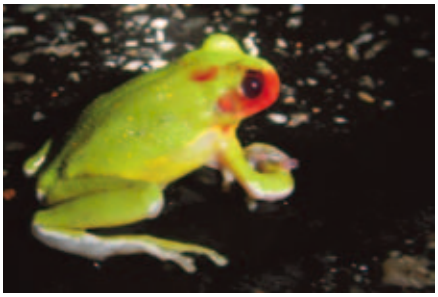
JOHNSON ET AL. (2010. *BioScience* 61:147–163) proposed that natural history collections (NHCs) are important sources of the long-term data needed to understand how biota respond to ongoing anthropogenic climate change. These include taxon occurrence data for ecological modeling, as well as information that can be used to reconstruct mechanisms through which biota respond to changing climates. The full potential of NHCs for climate change research cannot be fully realized until high-quality data sets are conveniently accessible for research, but this requires that higher priority be placed on digitizing the holdings most useful for climate change research (e.g., whole-biota studies, time series, records of intensively sampled common taxa). Natural history collections must not neglect the proliferation of new information from efforts to understand how present-day ecosystems are responding to environmental change. Such new directions will require a strategic realignment for many NHC holders to complement their existing focus on taxonomy and systematics. To set these new priorities, NHC holders and global change biologists must establish strong partnerships.

GEORGE ZUG

Research employing natural history collections is critical for assessing long-term trends, such as effects of anthropogenic climate change. Here, Kate Jackson examines a cobra at the National Museum of Natural History (Smithsonian Institution).

Traffic, Urbanization, and Amphibian Encounter Rates

Although amphibians have relatively high rates of road mortality in urban areas, the conditions under which traffic threatens the survival of local amphibian populations remain unclear. In the Sandhills region of North Carolina, **SUTHERLAND ET AL.** (2010. *Conservation Biology* 24:1626–1635) counted living and dead amphibians along two transects (total length 165 km) established on roads in areas with varying degrees of urbanization. They found 2,665 individuals of 15 species, and amphibian encounter rates declined sharply as traffic and urban development increased. Regression-tree models indicated that 35 amphibians/100 km occurred on roads with <535 vehicles/day, whereas the encounter rate decreased to only 2 amphibians/100 km on roads with >2,048 vehicles/day. Although mortality rate peaked at higher traffic levels (47% dead on roads with >5,200 vehicles/day), the number of dead amphibians was highest at low levels of traffic. This suggests that areas where amphibian mortality is concentrated may actually contain the largest populations remaining on a given road transect.



RON SUTHERLAND

This unfortunate Barking Treefrog (*Hyla gratiosa*) looks alive, but didn't move when nudged. Upon closer examination, fire ants were already aggregating to start their feast.

NATURAL HISTORY RESEARCH REPORTS

Predators Restrict Foraging Behavior in Black Spiny-tailed Iguanas

The presence of a predator may have direct and indirect effects on the behavior of prey. Although altered behavior may help prey avoid predators, it also can have a potential impact on critical activities such as foraging. Predator-prey interactions are routinely studied in laboratory-based experiments owing to the perceived difficulties of conducting such experiments in natural settings. **FARALLO ET AL.** (2010. *Phyllomedusa* 9:109–119) conducted an experimental study


CLINT BOAL

Black Spiny-tailed Iguanas (*Ctenosaura similis*) reduced their foraging efforts in the presence of a predator and a chemical cue to a predator.

under field conditions in Palo Verde National Park in northwestern Costa Rica to assess the behavioral responses of Black Spiny-tailed Iguanas (*Ctenosaura similis*) to the presence of predators and predator cues. Free-roaming iguanas were offered mango in designated areas in the presence of a predator (*Boa constrictor*), a predator cue (*B. constrictor* feces), and a control (no predator or predator cue). Results indicated that iguanas reduced their foraging efforts in the presence of both a predator and its cue.

Courtship Behavior in the Northern Spectacled Salamander (*Salamandrina perspicillata*)

Knowledge of reproductive behavior in the Italian endemic Northern Spectacled Salamander (*Salamandrina perspicillata*) is incomplete, and the only detailed observations were made just once in a terrarium. **Bruni and Romano** (2011. *Amphibia-Reptilia* 32:63–76) described many aspects of terrestrial courtship behavior, such as male alert posture, substrate trail-marking, approach and pursuit, tail-undulation and vent-swinging, and spermatophore deposition and pick-up. The courting pair follows an ellipsoidal track. A spermatophore is deposited by the male just in front of the female, who will reach the spermatophore as she continues to circle. No body contacts were observed during the courtship. Tail movements play a key role in the communication between sexes as well as between antagonistic males. Male-male combat involves biting as the main deterrent. The authors found that the mating season in wild populations is in the spring, differing from that reported previously for mating in captivity


GIACOMO BRUNI

Male Northern Spectacled Salamanders (*Salamandrina perspicillata*) engage in varied courtship behaviors that include alert postures that might be combined with or extended to elevating the anterior body.

(winter) or extrapolated from the beginning of sperm storage (autumn).

Reproduction in the Giant Garter Snake (*Thamnophis gigas*)

Halstead et al. (2011. *The Southwestern Naturalist* 56:29–34) used mixed-effects models to examine relationships of reproductive characteristics of the Giant Garter Snake (*Thamnophis gigas*). Neonates from larger litters had lower mass, and mass of neonates also was affected by random variation among mothers. The length of the mother did not affect the relative mass of litters; however, the data suggested that longer mothers expended less reproductive effort per offspring than shorter mothers. The authors detected random variation in the length of neonates among mothers, but these lengths were not related to length of the mother or size of the litter. Mean size of litter varied among years, but little evidence existed for a relationship between size of litter or mass of litter and length of mother. Sex ratios of neonates did not differ from 1:1.


MATT MESHRY

The Giant Garter Snake (*Thamnophis gigas*), with a historical range throughout the Central Valley of California, is listed as vulnerable on the IUCN Red List. Because of the loss of natural habitat, this snake now relies heavily on rice fields in the Sacramento Valley, but it also uses managed marshes in protected areas. Studies of reproductive biology are essential for developing and implementing appropriate management plans. Here, a smaller male is courting the much larger female.

NEWSBRIEF

Colombian Easter Fare: Iguana, Turtle, or Mega-rodent

Green Iguana, Slider Turtles, and the world's largest rodent, the Capybara — but it's not a trip to the zoo. It's a traditional Easter dinner in Colombia. "This is the season we have them all coming in," said nutritionist Carolina Rangel, at a center for confiscated animals in Bogotá, the Colombian capital, in reference to about 30 confiscated "outlawed" Slider Turtles, common here and in Venezuela, as well as a rogue Green Iguana officials picked up on a bus.

Sometimes problems crop up when the animals escape from their "caretakers," especially during the busy Easter season; many Colombians travel for hours on intercity buses to spend the holiday with family and prepare special meals. "People bring them in (from far-flung provinces) secretly, even stashed in suitcases so they can eat them with relatives, or sell them at open-air markets,"

In many Latin-American nations, iguanas, such as this Green Iguana (*Iguana iguana*), are eaten the year around, but because the Catholic Church does not classify them as "meat," consumption increases during lent and often culminates in a special Easter treat.

said local environmental official Andres Alvarez, a veterinarian.

Colombia has wildly varied geography, with tropical Pacific and Caribbean coasts and cooler Andean mountain climes that support a huge range of plant and animal life. Recipes based on local animals — instead of imported ones — have close ties to the northern and northwestern parts of the country. They often are served in the age-old recipes of indigenous peoples. Among the mouthwatering seasonal treats: Turtle eggs omelets, iguana soup, cayman or turtle stew, which is served with coconut rice and fried yucca, all washed down with cold beer. "Colombia's gastronomic wealth is a reflection of the country's biodiversity," the world's second greatest after Brazil, said anthropologist Julian Estrada.

How the custom evolved of eating these meals at this time — the Christian celebration of Easter — is not so clear, but people who lived along rivers in what is modern-day Colombia ate all of these animals before the Spanish colonial era started in the 15th century. "For our indigenous people, the sleeper turtle and iguana are historically symbolic, mystical animals and part of age-old customs. Ultimately, what happened was that the (Roman) Catholic calendar's tradition ended up melding with the fact that those animals are plentiful" during the spring Easter period, said anthropologist Ramiro Delgado. So, while many Colombians are eagerly awaiting the arrival of an exotic little something on their Easter table, hundreds of others are trying to make sure that passengers on intercity buses are people and not animals.

JOHN F. BINNS

Capybara (*Hydrochoerus hydrochaeris*) are the world's largest rodent and can occasionally top 100 kg. Although not endangered, Colombian laws prohibit hunting during the Easter season. Nevertheless, they frequently serve as seasonal treats, and the authorities try to balance protection of the species with respect for indigenous Colombian traditions.

Rodolfo Mendoza, the chief of the environmental police in Barrancabermeja, northwest of the capital, said that his department recently intercepted what amounted to a mini-herd of eight Capybara (the world's largest rodent that can occasionally top 100 kg). Although not endangered, they are not supposed to be hunted at this time of the year. Authorities have to balance trying to protect the species while respecting indigenous Colombian traditions. Consequently, the hunting and sale of turtles, iguanas, and small crocodiles is illegal — but, at the same time, they are consumed by people who eat them to survive in communities where food sources are limited. The Environment Ministry says that in just four years, more than 100,000 live river turtles have been confiscated. "Our real problem is just trying to manage the use of these animals, not turning consumption into some big crime," said government biodiversity expert Claudia Rodriguez. "Above all because in some poor rural areas, they are the only food people have."

Adapted from a news article by
Michael Cancela-Kieffer
AFPrelaxNews, 21 April 2011

Editors' Remarks

DOUGLAS SHERRIFF

Morelet's Treefrog (*Agalychnis moreletii*) at the Chester Zoo.

The "Focus on Conservation" (FOC) in this issue differs somewhat from those in the past. Instead of featuring a program or a project, we present one tool being used to address the global amphibian extinction crisis. "Amphibian Pods" have proven themselves invaluable in establishing assurance colonies of species that are threatened with extinction in the wild — in essence, trying to maintain genetically diverse populations until a cure for chytridiomycosis is found in hopes that these individuals can be used to reestablish or augment wild populations decimated by that infectious fungal disease. In addition, the pods can serve as educational tools in the native ranges of the affected species or to inspire contributions to aid in conservation efforts. Kevin Zippel, Paul Crump, Ron Gagliardo, Richard Gibson, Michael McFadden, and Tara Sprankle all contributed to the FOC. We thank them.

The Editors of *Reptiles & Amphibians*

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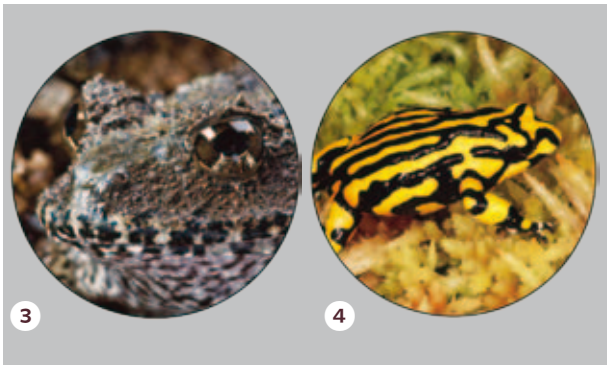
FOCUS ON CONSERVATION

Amphibian Pods

RONALD GAFLIARDO

RONALD GAFLIARDO



LEFT: RON HOLT RIGHT: MICHAEL MCFADDEN

Fig. 1 and 2: The "frogPOD" at the Atlanta Botanical Garden. Fig. 3: *Strabomantis bufoniformis*, a toad-like species in the family Eleutherodactylidae that is native to Panamá and Colombia, is being kept in the "pod" at Atlanta. Fig. 4: The "pod" at the Taronga Zoo houses critically endangered Southern Corroboree Frogs (*Pseudophryne corroboree*).

Amphibians are among the most imperiled groups of animals and plants. For every species of threatened bird or mammal, two or three amphibians are on the brink of extinction. The global conservation community has formulated a response to the amphibian extinction crisis in the Amphibian Conservation Action Plan (www.amphibianark.org/pdf/ACAP.pdf). An integral part of that response is the Amphibian Ark, in which species that would otherwise become extinct are maintained in captivity until the threats facing them can be mitigated and they can be secured in the wild. Without immediate captive management as a stopgap component of an integrated conservation effort, hundreds of amphibian species could become extinct.

The clever reuse of insulated cargo-shipping containers as amphibian rescue facilities was pioneered by Australia's Gerry Marantelli at the Amphibian Research Centre (see http://frogs.org.au/arc/container.php), a private facility that houses in these "amphibian pods" over three thousand threatened amphibians. Subsequently, other pods have popped up in Australia (Taronga Zoo, Tidnibilla Nature Reserve, Healesville and Currumbin Sanctuaries) as well as in Europe (Jersey and Chester Zoos), the U.S. (Phoenix Zoo, Atlanta Botanical Garden), Chile (Universidad de Concepción), and Panamá (El Valle Amphibian Conservation Center, Panama Amphibian Rescue Project).

Pods are ideal rescue facilities for amphibians. They are relatively inexpensive, often cheaper than new "traditional" construction. A 320-ft^2 pod, coincidentally about the perfect size to house an entire rescue population of an average-sized amphibian, costs ~$50,000 including purchase, refurbishment, outfitting (with shelves, tanks, etc.), shipment to point of use, installation, and a generator. Containers are available everywhere in the world, often as discounted "retired" units that are still fit for use. Pods are easily modified to meet particular specifications; every major port in the world seems to have a company that specializes in retrofitting units for other uses (offices, storage, housing, etc.). They are modular, easily placed adjacent to or on top of each other, and so can be added one at a time to increase capacity at a given facility, which is ideal when space is limited. They also are mobile and made to be easily transported, so they can be delivered "ready-to-go" to a point of use, or if need be, relocated from one site to another (try doing that with traditional construction!). All they need is a concrete pad and hookup to local water and electrical supplies. Finally, pods are easily modified to be an attractive exhibit by adding large viewing windows and graphics.

Pods in Australia are being used to rescue Corroboree Frogs (*Pseudophryne corroboree*, *P. pengilleyi*) and Spotted Treefrogs (*Litoria spenceri*). Pods in Jersey and Chester house Mountain Chickens (*Leptodactylus fallax*), Agile Frogs (*Rana dalmatina*), Morelet's Treefrogs (*Agalychnis moreletii*), and Green-eyed Frogs (*Lithobates vibicarius*). The Phoenix pod housed Chiricahua Leopard Frogs (*Lithobates chiricahuensis*) for over 10 years before moving them to the Native Species Conservation Center, and the Atlanta pod maintains several rescued Panamanian species. The Chilean pod houses Darwin's Frogs (*Rhinoderma darwinii*) and the pod in El Valle is being set up for Panamanian Golden Frogs (*Atelopus zeteki*). All of these species are threatened regionally or globally.

For more information about the global effort to rescue amphibians, see www.AmphibianArk.org.

WILLIAMS, PARKER

In 1723, Paul Dudley described "three Sorts, or Kinds," of Timber Rattlesnake (*Crotalus horridus*) "distinguished by their Colour, *viz.* a yellowish Green, a deep Ash Colour, and a black Sattin." This individual from the Adirondacks of New York represents the "deep Ash Colour." See the Historical Perspective on p. 122.