

DISTRIBUTION AND ECOLOGY OF THE INTRODUCED
AFRICAN RAINBOW LIZARD, *AGAMA AGAMA AFRICANA*
(SAURIA: AGAMIDAE), IN FLORIDA

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ABSTRACT: We document populations of the introduced African rainbow lizard (*Agama agama africana*) in Homestead, Miami-Dade County; Hollywood, Broward County; Palm City, Martin County; Punta Gorda, Charlotte County; and Sanford, Seminole County. The Homestead and Punta Gorda populations have been established for over 10 yr and have expanded at least 0.5 km from the point of introduction. The Palm City population has been established since 1999 and the Sanford population since 2000. All agamas were observed in urban or suburban situations perched on walls, rooftops, bridges, rocks, sidewalks, curbstones, or trees. We collected 33 voucher specimens from five populations 28 March 2002–11 March 2004. Maximum clutch size and maximum snout-vent length (SVL) of male and female *A. a. africana* in Florida exceeded those in native Nigerian populations. All adult females (≥ 94 mm SVL) collected May–August contained 5–18 vitellogenic follicles or oviductal eggs, but a female collected on 19 September was not gravid. Monitoring should be conducted to determine whether the species might eventually invade natural habitats and its potential impacts on native wildlife species.

Key Words: *Agama agama africana*, African rainbow lizard, distribution, ecology, reproduction, introduced species, Florida

THE SUBTROPICAL climate of southern Florida has allowed the establishment and survival of many non-indigenous reptile species, particularly lizards of tropical origin. Florida presently contains the largest number of non-native amphibian and reptile species in the United States, but the list of 36 introduced species provided by Butterfield and co-workers (1997) did not include *Agama agama*, which has established populations in at least five counties in Florida. Bartlett and Bartlett (1999) reported *A. agama* as occurring near reptile dealerships in two suburban areas in Broward County and one area in Miami-Dade County, and they expressed uncertainty as to whether the species would “spread farther or succumb to climatic conditions that are very different from its native habitat.”

Wilson and Porras (1983) noted a colony of *A. agama* (Linnaeus 1758) established since 1976 in the vicinity of NW 70th Avenue and 70th Street, Miami, Miami-Dade County. Voucher specimens of *Agama a. africana* Hallowell 1844 were collected from this Miami colony (LSUMZ 36647, UF 43490), but Wilson and

Porras (1983) did not include *A. agama* in their list of introduced herpetofauna because the population was apparently extirpated when the area was demolished to construct a rapid transit system.

In this paper, we describe the distribution, habitat use, and source of introduction of two large, well-established populations of *A. a. africana* in Homestead, Miami-Dade County, and Punta Gorda, Charlotte County, and three smaller populations in Sanford, Seminole County; Palm City, Martin County; and Hollywood, Broward County. Krysko and co-workers (2004) have already documented populations in Homestead, Punta Gorda, and Sanford, but we provide reproductive data for these populations.

In the early 1990s, agamas were either released or escaped during Hurricane Andrew at the residence of a reptile dealer near the junction of Coconut Palm Drive (SW 248th Street) and SW 163rd Avenue in the Redland area of Homestead (25° 32.17'N, 80° 27.13'W). The same reptile dealer responsible for the Homestead population subsequently relocated to 6362 Citrus Boulevard SW, which is ca. 11.7 km SW of Palm City (27°03.84'N, 80°19.28'W), where ca. 20 *A. a. africana* escaped or were released in 1999 and became established (Powell, 2003). An agama population also occurs in the vicinity of a reptile dealership on the south side of Stirling Road (State Road 848), east of its junction with NW 65th Avenue in Hollywood (26°02.76'N, 80°13.15'W). Approximately 17 years ago, a reptile dealer in Punta Gorda released *A. a. africana* at his private residence at 722 Solana Loop East (26°56.48'N, 82°01.81'W) (Clark, 2003), which is on the north side of State Road 17 (East Marion Avenue) ca. 1.3 km west of Interstate 75. The most northerly known agama population occurs in Sanford (28° 46.18'N, 81° 16.84'W). This population was introduced in 2000 when ca. 40 agamas escaped or were released from a nearby reptile store, which has since relocated (Ward, 2003).

Agama agama is often referred to as the African red-headed agama or common agama in the United States pet trade and popular literature (Frank and Ramus, 1995; Bartlett and Bartlett, 1999), and in scientific literature as the African rainbow lizard (Romer, 1953; Daniel, 1960; Chapman and Chapman, 1964; Harris, 1964; James and Porter, 1979; Cloudsley-Thompson, 1981; Sodeinde and Kuku, 1989). *Agama agama* is found in tropical, sub-Saharan Africa from Senegal east to Ethiopia and south to northern Angola and southern Tanzania. The coloration and pattern of this species varies over its geographic range, and nine subspecies are currently recognized (EMBL Reptile Database, 2003). The subspecies in Florida is apparently *A. a. africana*, which is imported for the pet trade from Ghana, Togo, and possibly Benin (Foster, 2003). Dominant, reproductive males in the five Florida populations we examined have tri-colored tails as described for this subspecies by Harris (1964) and are identical to photographs by James and Porter (1979) and Cloudsley-Thompson (1981) of *A. agama* from Ghana and Nigeria in West Africa. The reproductive coloration of adult males of *A. a. africana* consists of an orange head, indigo blue or black body and limbs, and a tail that is bluish white at the base and has an orange middle segment and black tail tip (Harris, 1964).

Agama agama is a sit-and-wait predator, feeding mostly on ants, orthopterans, and beetles (Harris, 1964; James and Porter, 1979) but occasionally on vegetation

during the dry season (Chapman and Chapman, 1964; Cloudsley-Thompson, 1981). In Africa, a few instances have been reported of *A. agama* preying upon their own young, small snakes, birds, and mammals (Harris, 1964; Cloudsley-Thompson, 1981).

METHODS—We visited all known sites for *A. agama* in Florida and checked out reported sightings, recording the presence of *Agama* and other introduced lizard species. One to five visits were made between 28 March 2002 and 11 March 2004 to Sanford, Punta Gorda, Palm City, Hollywood, Miami, Homestead, and Key Largo. Agamas were collected by hand, by using a blowgun that shot tapered corks, or by fishing using crickets for bait (Krysko, 2000). Voucher specimens and photographs were deposited in the Florida Museum of Natural History (FLMNH), University of Florida (UF collection). We reviewed the literature and obtained additional specimens from Everglades National Park (EVER) and the Louisiana State University Museum of Natural Science (LSUMZ) to corroborate identification.

We dissected all adult females collected to determine the number of oviductal eggs or follicles present. A female was considered ovigerous if the mean length of her elliptical oviductal eggs was ≥ 12.0 mm, and she was considered fecund if developing follicles were > 3.5 mm in diameter (Daniel, 1960).

RESULTS—We observed agamas at seven sites in Florida but consider them to be established in only five areas: Sanford, Punta Gorda, Palm City, Hollywood, and Homestead. On 26 May 2003 in Sanford, we observed 13 *A. a. africana* on or around the large, vacant SunTrust Bank building at 3000 South Orlando Drive, five individuals farther north on the abandoned Gino's Café, and one individual perched on a boulder at the intervening car dealership. We collected six adult females (UF 136983–8). Most individuals were observed on brick buildings up to three stories tall, and the population was apparently very localized, although the surrounding habitat appeared suitable for colonization. The only other exotic lizard species observed was the brown anole (*Anolis sagrei*).

At three locations in Punta Gorda, we observed 22 agamas in rainy weather on 3 June 2003. At 1410 hr, three adult females were observed and one was collected (UF 137017) on the wall of a Circle K store (26°56.46'N, 82°01.89'W) and on a nearby oak (*Quercus* sp.) tree. At 1430 hr, 12 adults and one hatchling were observed on Solana Loop West (26° 56.56'N, 82° 01.86'W). At 1500 hr, two adult males and four adult females were observed on Solana Loop East at the original introduction site. On 4 June 2003, at least 23 adults and two hatchlings were observed at 1450 hr under the State Road 17 overpass of Lavilla Road (26° 56.37'N, 82° 01.64'W). One adult male, nine adult females, and two hatchlings were collected here (UF 137043–55). On 3 July 2003, four adults were observed at 1630 hr under the State Road 17 overpass of Florida Street (26° 56.30'N, 82° 01.50'W), ca. 0.6 km SE of the introduction site. Most agamas in Punta Gorda were observed on concrete embankments or the infrastructure of bridges, walls and roofs of buildings, or trees. Other exotic lizard species observed were the brown anole and red-sided curly-tailed lizard (*Leiocephalus schreibersii*) (Krysko et al., 2004).

At the Palm City site, we observed an adult female, collected two juveniles (UF 137409–10), and observed approximately 13 other juveniles or hatchlings on limestone rocks on 22 August 2003. We did not arrive at this site until 1815 hr on an overcast afternoon, which probably accounted for the paucity of adults observed.

Other exotic lizard species observed or reported introduced here (Powell, 2003) were the large-headed anole (*Anolis cybotes*), Guyana collared lizard (*Tropidurus hispidus*) (UF 137411–3), and spiny-tailed iguana (*Ctenosaura* sp.).

At the Hollywood site, we captured one adult male (UF 137674) and observed three females on property adjacent to a reptile dealership at 1430 hr on 22 August 2003. Other exotic lizard species observed around the reptile dealership were the brown anole, knight anole (*Anolis equestris*), brown basilisk (*Basiliscus vittatus*), common house gecko (*Hemidactylus frenatus*) (UF 137408), and flying gecko (*Ptychozoon lionotum*) (UF 137744).

We did not attempt to determine the exact geographic limits of the *A. a. africana* population in Homestead, but they were readily observed perched on sidewalks, low oolitic limestone and brick walls, and trees in front of the Redland Middle School at the junction of Coconut Palm Drive and SW 162nd Avenue and around houses and tropical plant nurseries up to at least three blocks from the school. We observed 25 individuals and collected one adult male (UF 131521) at the school and across the street on 28 March 2002. On 29 May 2002, we observed five adults and two hatchlings, collecting four adults (UF 132696–700). On 19 September 2002, we observed 20 individuals and collected one adult female (UF 134222). At 0930 hr on 22 August 2003, we collected two adult females (UF 137662–3) and observed two other adult females, one adult male, and ca. 20 juveniles or hatchlings during and after a rain shower. At 1300 hr on 11 March 2004, we observed three dominant reproductive males and 12 other adults at the school; the two individuals collected (UF 141218–9) resembled females but proved to be males upon dissection. Other exotic lizard species observed in the area were the brown anole and Amerafrican house gecko (*Hemidactylus mabouia*).

Individual agamas have been observed in the wild in at least two other counties in Florida, but we do not believe these sightings indicate reproducing populations. On 22 August 2003, we photographed an adult male *A. a. africana* (UF 141422) on the property of a reptile dealer at 16225 SW 172nd Ave., Miami. Other exotic lizard species observed were the giant ameiva (*Ameiva ameiva*) (UF 137671), common house gecko, golden gecko (*Gekko ulikovskii*), bark anole (*Anolis distichus*), brown anole, green iguana (*Iguana iguana*), and Nile monitor (*Varanus niloticus*). A male *A. a. africana* was photographed (UF 137389) in July 2003 in Buttonwood Bay, subdivision on Key Largo, Monroe County (25°03.94'N, 80°28.46'W). This male and smaller, brown lizards were frequently observed (Kriss, 2003). During a visit on 21 August 2003, we did not observe the male, and the smaller lizards were not female agamas but instead northern curly-tailed lizards (*Leiocephalus carinatus armouri*) (Krysko et al., 2004).

All adult females collected 26 May 2002–26 August 2003 from Sanford, Punta Gorda, and Homestead contained either vitellogenic follicles or oviductal eggs, but a nongravid female was collected on 19 September 2002 in Homestead. A gravid female collected in Punta Gorda on 15 February 2004 oviposited eight infertile eggs on 9 March (Eddington, 2004). The mean length of oviductal eggs from eleven females ranged from 12.1 to 19.3 mm, and the mean diameter of follicles from 10 females ranged from 4.0 to 11.2 mm. The mean number of oviductal eggs was $9.0 \pm$

1.6 (n = 11), and the mean number of follicles was 9.7 ± 3.3 (n = 11). Clutch size (oviductal eggs or follicles) ranged from five to 18 and was positively correlated with snout-vent length (SVL) ($r^2 = 0.22$, $F_{1,20} = 5.67$, $P = 0.03$). Of 10 females collected in Punta Gorda on 3–4 June 2003, seven contained oviductal eggs, and the remainder contained developing follicles. Oviductal eggs probably represented second clutches, whereas follicles probably represented either second or third clutches. Two hatchlings captured in Punta Gorda on 4 June 2003 (UF 137053–4) measured 42 mm SVL and probably hatched from eggs laid > 60 days earlier. Overall, we captured 23 adult females ranging in size from 94 to 123 mm SVL (mean = 111 mm), four dominant reproductive males (122–154 mm SVL), and two males in nonbreeding coloration (92 and 105 mm SVL).

DISCUSSION—We observed agamas perched on walls, rooftops, concrete curbs, bridges, rocks, and trees, and occasionally on the ground underneath shrubbery, on lawns, on sidewalks, or in parking lots. We never observed agamas in natural habitats. Even in Africa, *A. a. africana* is seldom observed in undisturbed habitats; instead, it is primarily found in close association with humans and is often the most frequently seen reptile species in urban and suburban situations (Romer, 1953; Daniel, 1960; Harris, 1964; Grandison, 1968; James and Porter, 1979; Cloudsley-Thompson, 1981; Sodeinde and Kuku, 1989). *Agama a. africana* is a tree-dwelling species that primarily inhabits savannas, but it has expanded its range into shrubland and forest areas that have been cleared for farms, villages, lawns, roads, trails, or buildings (Daniel, 1960; James and Porter, 1979). In rainforest areas, *A. a. africana* is restricted to living on the walls of houses (Harris, 1964; Cloudsley-Thompson, 1981). Manmade structures and debris piles in disturbed habitats are preferred perching and roosting sites (Grandison, 1968). Agamas are extremely fast, and when approached, quickly seek shelter in cracks on walls, on trees or shrubs, beneath debris, or in or under concrete structures (Cloudsley-Thompson, 1981).

In Africa, *A. a. africana* is especially active on hot sunny days and attempts to avoid wind and rain (Cloudsley-Thompson, 1981). In Florida, we sometimes observed agamas during rainy weather and immediately after rain showers, with juveniles and females appearing most tolerant of wet conditions. The more northerly agama populations in Florida are probably reliant on warm refugia to escape occasional freezing temperatures. The air temperature in Sanford on 24 January 2003 reached -2.8°C . We observed agamas in Sanford entering holes in the walls of abandoned buildings and stormwater grates that led to buried pipes. We suspect that this population is able to survive low winter temperatures by accessing the interiors of buildings or underground refugia.

In Africa, *A. a. africana* oviposits multiple clutches consisting of 3–9 eggs each, with five or six eggs being most common (Daniel, 1960; Harris, 1964). In comparison, females from Florida populations contained 5–18 (mean = 9) oviductal eggs or vitellogenic follicles. We suspect agamas in Florida oviposit at least three clutches annually, giving a minimum annual reproductive output of approximately 27 eggs. In Nigeria, females become sexually mature at ca. 90 mm SVL and ca. 14

months of age (Harris, 1964; Sodeinde and Kuku, 1989). In Liberia, both sexes attain sexual maturity at ca. 80 mm SVL and their second year of life (Daniel, 1960). Our smallest gravid female (94 mm SVL) contained five follicles.

Considering the collection dates of gravid females and hatchlings, the size of follicles in dissected females, and assuming an incubation period of ca. 58 days (Sodeinde and Kuku, 1989), the breeding season in Florida probably begins in February. African hatchlings measured 30–38 mm SVL (Romer, 1953; Daniel, 1960; Harris, 1964), indicating that small individuals (42 mm SVL) collected on 4 June 2003 were probably not recent hatchlings. In its native range, *A. a. africana* breeds year-round in the rainforest belt and Cape Coast, Ghana (Daniel, 1960; James and Porter, 1979), but in drier savanna regions, the breeding season coincides with the rainy season (Harris, 1964). Cool weather probably restricts the breeding season in Florida, particularly for the more northerly populations. Females still contained well-developed eggs in late August, but a female collected in 19 September was not gravid, suggesting that the breeding season ends in late summer in Florida.

We observed relatively few hatchlings in May and June, as also noted by Bartlett and Bartlett (1999). For the first two months of life, hatchlings avoid adults and spend most of their time in dense vegetation, often near the ground (Harris, 1964). By four months of age, juveniles typically live gregariously within a particular territorial group (Harris, 1964). During visits in August to the Homestead and Palm City populations, however, we observed numerous hatchlings and juveniles using the same perches as adults, and hatchlings and juveniles were also observed in August in the Sanford population (Ward, 2003). In Homestead, we saw hatchlings most frequently where the oolitic limestone wall was broken resulting in numerous interstices in the jumble of rock fragments. These small spaces presumably provided hatchlings with shelter from adults or other potential predators.

Our largest female (123 mm SVL; UF 137043) and male (154 mm SVL; UF 137052) exceeded the maximum size found for a female (119 mm SVL) and male (148 mm SVL) in two Nigerian populations (Sodeinde and Kuku, 1989). In Nigeria, the mean SVL of adult females was 97 mm ($n = 68$) in one population (Harris, 1964) and 104 mm ($n = 28$) in another population (Sodeinde and Kuku, 1989), compared with 111 mm SVL ($n = 23$) in Florida. In Nigeria, adult males averaged 128 mm SVL ($n = 50$) (Harris, 1964) or 125 mm SVL ($n = 40$), which corresponds to ca. 22 months of age (Sodeinde and Kuku, 1989).

Presently, populations of *A. a. africana* are established in at least five counties in Florida, and two of the populations have persisted for at least 10 years and dispersed at least 0.5 km from their point of introduction. Additional undocumented populations are probably present. We learned that most *A. a. africana* populations in Florida resulted from many individuals escaping from reptile dealers (Hurricane Andrew might have been responsible for the Homestead population) or being intentionally released. Reptile dealers or hobbyists sometimes release lizards in attempts to establish feral populations for future exploitation (Krysko et al., 2003), but we suspect that this is not the primary source of introduced *A. a. africana* in Florida. Imported *A. a. africana* are readily available and inexpensive, and capturing feral individuals without damaging them would be difficult and uneconomical,

unless accessible nocturnal refugia could be located. *Agama a. africana* are typically imported for \$0.75 and wholesale for \$1.50–\$3.00 (Powell, 2003). Specimens tend to do poorly in captivity, often failing to settle down or feed well (Harris, 1964). Some agamas are probably released because they are nonsalable due to low market demand or poor physical condition, whereas others are released because persons desire seeing them around their residences. Conversations with local residents of neighborhoods containing agamas indicate that they enjoy observing them and do not want to see them captured. The general public is usually unaware that it is illegal to release non-indigenous animal species in Florida.

Some confusion exists as to the identity of all specimens of agamas observed in Florida. Bartlett and Bartlett (1999) photographed a dominant male that was one of many individuals observed on the walls of a reptile dealership in Hollywood, Broward County (Bartlett, 2003). During a visit there in August 2003, we observed four adult agamas, and the adult male collected was *A. a. africana* and did not resemble the aforementioned photograph, which was possibly of an East African subspecies. According to the reptile dealer, large numbers of agamas are not currently present, and earlier observations may have been after many had recently escaped. In 1996, a lizard (EVER 304176) identified as the common spiny agama (*A. hispida*) was collected at the corner of Coconut Palm Drive and SW 167th Avenue, the introduction site for the *A. agama* population in Homestead. We examined this specimen and identified it as the hardun or starred agama (*Laudakia [Agama] stellio*), which is native to Greece, southwestern Asia, and northern Egypt (Arnold, 2002). *Laudakia stellio* has occasionally been collected in Miami-Dade County but is apparently not established (Meshaka et al., 2004). Another *L. stellio* that was misidentified as *A. hispidus* (EVER 308085) was collected in 1999 ca. 6.5 km SSW of the Redland Middle School.

More populations of *A. a. africana* may become established in the southern half of peninsular Florida. The agamas we observed were restricted to open, human-altered environments, where they tended to use vertical surfaces, such as walls or bridges, containing crevices or holes. Although agamas presently occur only in suburban or urban situations, we suspect this species could survive in open, agricultural areas with suitable perch sites and refugia. Like many other exotic lizard species in Florida, *A. a. africana* may be unable to successfully establish populations in undisturbed natural habitats. Impacts of agamas on native wildlife species in Florida are unknown.

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