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A REVIEW OF THE COLONIZATION DYNAMICS OF THE NORTHERN CURLY-TAILED LIZARD (*LEIOCEPHALUS CARINATUS ARMOURI*) IN FLORIDA

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ORIGINAL RANGE, INTRODUCTION, AND DISTRIBUTION IN FLORIDA

The northern curly-tailed lizard (*Leiocephalus carinatus armouri*) is endemic to the islands of the Little Bahama Bank, with other subspecies found in the Great Bahama Bank, Cayman Islands, and Cuba (Schwartz and Thomas 1975, Schwartz and Henderson 1991).

Palm Beach and Martin Counties.—Duellman and Schwartz (1958) reported the species as an introduced exotic in Florida in Palm Beach County. The initial introduction was reported to have occurred as a result of 20 pairs released by a resident near Pendleton and Clarke Avenues on the Island of Palm Beach during the 1940s (Weigl et al. 1969). By 1959, the range of the species had expanded at least 20 city blocks (King 1960, Weigl et al. 1969). The 1959 range boundaries were Royal Poinciana Way (north), Clarke Avenue (south), Atlantic Ocean (east), and the Intracoastal Waterway (west) (King 1960). By 1968, northern curly-tailed lizards were common from as far north as the Palm Beach Country Club, and as far south as South Ocean and Sea Grape Circles, a range extension of 3.21 km north and 5.63 km south (ca. 4.02 km^2) (Weigl et al. 1969). Weigl et al. (1969) also found a small population on the mainland at the base of where the Flagler Bridge touches West Palm Beach from the Island, and also believed that the northern curly-tailed lizard could further extend its range 2.85 km north to the Palm Beach Inlet, and 12.2 km south to the Boynton Beach Inlet at the southern end of Palm Beach Island. However, by 1975, disjunct populations of this species were firmly established on the Florida mainland at the Flagler Bridge approach and near the Royal Palm Way Bridge approach (Callahan 1982). By 1981, northern curly-tailed lizards also were established on the mainland at the Southern Boulevard Bridge and Lake Avenue Bridge approaches (Callahan 1982). Smith and En-

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geman (2003) reported them as abundant since 1986 at Woolbright Road and the Intracoastal Waterway (ICW), an additional 3.4 km south of the speculated southern limit (Weigl et al. 1969).

Northern curly-tailed lizards now have been reported to the north in Martin County (Hauge and Butterfield 2000, Smith and Engeman 2002, Smith et al. 2004, Smith et al. in press), which rests on the northern border of Palm Beach County. A recent survey of this geographically expanding population conducted in September 2002 documented a relatively contiguous 90 km Atlantic coastline south-north range from at least Lighthouse Point, Broward County to Hobe Sound, Martin County (Smith et al. 2004). The species also was found an additional 5.5 km inland within Jonathan Dickinson State Park in Martin County in 2003 (H. Smith et al., unpubl. data), with other reliable sightings reported for the park (M. Nelson, Florida Dept. Environmental Protection, pers. observ.).

Callahan (1982) calculated the range expansion area of the Island of Palm Beach population from 1945-1981 as averaging 50.0 ha/y, and for the Palm Beach County mainland population from 1968-1981 as 84.2 ha/y. Smith et al. (2004) reported an 80 km Atlantic coastline linear range expansion on the mainland of at least 46.3 km south, and 34.1 km north, beyond the 1968 island data in 34 years, or about 2.4 km/y. average. Comparatively, this rate of linear range expansion was 2.7 times that for the 9 years from 1959 to 1968 (Weigl et al. 1969, Smith et al. 2004).

Dade County.—A second early population identified as *L. c. virescens* was reported prior to the 1940s from the north Miami area, Dade County (Barbour 1936, King 1960), but apparently was later extirpated (Duellman and Schwartz 1958). *L. c. armouri* was reported at Virginia Key, and at Crandon Park on Key Biscayne in 1965 (King and Krakauer 1966); and, the *L. c. coryi* subspecies also was reported on Virginia Key and Key Biscayne (Truitt and Ober 1973). An additional population of *L. c. armouri* was discovered in 1982 by D. Wilson at the Port of Miami (Callahan 1982), which apparently has been little studied. Bartlett and Bartlett (1999) list Dade County as being occupied but specific locations are not provided. Conant and Collins (1998) list Key Biscayne, Virginia Key, and the Port of Miami in their locations.

Other Populations.—Widely disjunct, allopatric populations or individuals also have been verified from the barrier island containing Cocoa Beach in Brevard County (Krysko and King 2002), Chokoloskee Island in Collier County (McCoid 2002), and John Pennekamp Coral Reef State Park on Key Largo in Monroe County (J. Duquesnel, Florida Dept. Environmental Protection, pers. comm.). Another disjunct population was found in Florida City, Dade County (Meshaka et al. 2004). Individual lizards also have been sporadically reported at a site in Se-

bastian Inlet State Park at the juncture of Indian River and Brevard counties during 1999-2001 (R. Johns, Florida Dept. Environmental Protection, pers. observ.); but, a thorough search of the area on 26 March 2003 resulted in no findings (HTS and A. Bard unpubl. data). J. Walsh, Florida Fish and Wildlife Conservation Comm. (pers. comm.) reported a single lizard in late 2001 or early 2002 in a parking lot at the junction of State Road 60 and Indian River Boulevard in Vero Beach [Indian River County]. Since it was crawling out from under his state vehicle at the time, he assumed it had hitched a ride with him. Layne (1987) reported a single individual in a parking lot near Sebring, Highlands County in 1986.

HABITAT

The northern curly-tailed lizard is a large ectotherm preferring disturbed, open, sandy rubble-strewn areas in coastal Florida (Meshaka et al. 2004, Smith et al. 2004). Other recent findings of this species also have been in and around habitat degraded by human infrastructure such as buildings (Hauge and Butterfield 2000), road intersections and parking lots (Krysko and King 2002, Smith and Engeman 2002, Smith et al. 2004, Smith et al. in press), and R.V. parks (McCoid 2002). Sightings frequently are in association with buildings, seawalls, and other human produced habitat conversions with gaps and recesses suitable for shelter and escape (Smith et al. 2004). At the Woolbright Road and Intracoastal Waterway site, northern curly-tailed lizards also occasionally take shelter in giant land crab (*Cardisoma guanhumi*) burrows when abruptly disturbed (HTS, pers. observ.).

Roads can be an important dispersal route for exotic amphibians and reptiles in Florida (Godley et al. 1981, Callahan 1982, Layne 1987, Campbell 1996, Meshaka 1996, McCoid 2002). Twice, on 19 May 1999 and 1 March 2003, individual northern curly-tailed lizards were discovered in apartment-complex garbage dumpsters at the Woolbright Road site, perched on top of piled trimmed vegetation which had been disposed of after maintenance landscaping (HTS, pers. observ.). It seemed unlikely that the lizards could escape the dumpsters, and presuming that they survived the trip to the municipal landfill, this could be another possible human-mediated dispersal mechanism. Likewise, commercial landscapers removing and transporting piles of trimmed vegetation from site to site, in open-bed trailers, as is common in south Florida, may be contributing to range expansions of this and other exotic lizards. In this regard, the 2.4 km/y in dispersal reported (op cit.) could be the combined result of increased opportunity for human-mediated dispersal and increase in habitat modification to the advantage of this lizard.

Refugia for many of the northern curly-tailed lizards at the Woolbright Road site are in large cracks at the interface of the blacktop parking lot surface and the cement sidewalks. Resurfacing of the parking lot with molten liquid tar during late April 2003 resulted in high lizard mortality (HTS pers. observ.).

Natural History, Key Behaviors, and Ecological Effects

Callahan (1982) reported the average size of adult, male, northern curly-tailed lizards collected in Palm Beach County was 9.2 cm SVL (range 8.1-12.8 cm, n = 14), and for adult females 8.7 cm (range 7.9-11.6 cm, n = 12). Meshaka et al. (2004) reported reproductively mature males from Palm Beach County averaged 94.7 ± 7.0 mm SVL (range 81.2-107.4 mm, n = 24), and reproductively mature females averaged 82.9 ± 7.5 mm SVL (range 70.2-94.9 mm, n = 21).

During warm days in Florida, adult northern curly-tailed lizards emerge from evening refugia approximately 1-2 hours after sunrise (Callahan 1982, HTS, pers. observ.). Callahan (1982) reported them to be active until early afternoon, and then return to refugia for 30-90 minutes before becoming active again until ca. 30 minutes before/after sunset. On cooler November and December days (0-10°C) he observed activity to start 60-90 minutes later in the morning and end 60-90 minutes earlier in the evening. Basking periods for this ectotherm range from minutes on warm (>26°C) days, up to two hours on sunny, but cool (0-10°C) days, depending upon temperature (Callahan 1982, Meshaka et al. 2004, HTS, pers. observ.). Meshaka et al. (2004) reported adults basking directly in sun, on open pavement, at an air temperature of ca. 33°C. The species is mostly terrestrial in habit but does ascend large trees to heights exceeding 3 m (Meshaka et al. 2004), and concrete staircases and trees in apartment complexes as high as ca. 6 m to bask and forage (HTS, pers. observ.). At times males are strongly territorial and engage in posture-threats including vertical head-bobbing, body push-ups, and various types of tail-curling (see discussion in Callahan 1982), as well as physical confrontations.

Curly-tailed lizards are carnivorous and capture prey by sitting and waiting vigilantly, then stalking, or more commonly rushing their prey (Callahan 1982, HTS pers. observ.). In Palm Beach County, the cricket (*Gryllus assimilis*, 17.2%), grasshoppers (*Melanoplus* spp. 10.1%), and isopods (Isopoda, 9.7%) were reported as the most common food items from 10 adult stomachs by percent total volume (Callahan 1982). Over the last decade at the Woolbright Road site in Palm Beach County unidentified beetles (Coleoptera), ants (Hymenoptera), and isopods have been common prey captures (HTS, pers. observ.). Meshaka et al. (2004) reported 60 lizards collected from Palm Beach County consumed mostly

beetles (73 stomach items), roaches (*Dictyoptera,* 22), and ants (80), with 11 other taxa marginally represented. Competition incidents of northern curly-tailed lizards rushing and capturing insect prey concurrently being stalked by anoles (*Anolis* spp.) have been observed (Callahan 1982, HTS, pers. observ.). Callahan (1982) observed two captures of exotic brown anoles (*A. sagrei*) by northern curly-tailed lizards and presumed that they were successfully consumed. HTS observed a small, unidentified *Anolis* sp. captured at the Woolbright Road site which was immediately taken into a structural crevice out of further view.

Based on collection of Palm Beach County specimens collected in July, Callahan (1982) concluded that females less than 73 mm snout vent length (SVL) were sexually immature (n = 3 with no reproductive activity <73 mm SVL, n = 9 with yolk-filled ovarian follicles 76-91 mm SVL, and n = *2* with enlarged oviducts without yolk-filled follicles which probably had recently deposited eggs 86-89 mm SVL). Based on observations of many newborn in September, Callahan (1982) also concluded that oviposition of eggs in Florida occurred in June or early July. Meshaka et al. (2004) reported yolk-filled follicles in 70% of females collected from Palm Beach County in May and 45.5% in July, and shelled eggs in 30% of females collected in May and 54.5% in July. Clutch sizes for 21 females averaged 4.0 ± 1.1 eggs, range 2-6 (Meshaka et al. 2004). Smith et al. (2004) reported successful breeding at a minimum of 87% of the sites where they found the species in 2002.

Previously listed potential predators of northern curly-tailed lizards in Florida included various falcons and hawks, domestic and feral cats (*Felis catus*), and the black racer (*Coluber constrictor*) (Callahan 1982, Meshaka et al. 2004). Over the last decade at the Woolbright Road site an estimated 10+ incidents of domestic/feral cats handling (carrying in jaws), or capturing northern curly-tailed lizards have been observed (HTS, pers. observ.). Various herons and egrets stalk them at the Woolbright Road site, but no captures have been observed at that location (HTS, pers. observ.). Unusual, opportunistic predators of northern curly-tailed lizards in Florida have included a juvenile Little Blue Heron (*Egretta caerulea*) foraging in a terrestrial situation (Smith and Engeman 2004), and a great barracuda (*Sphraena barracuda*) (Smith and Engeman 2003).

SUMMARY AND DISCUSSION

As with many other tropical herpetofauna introduced into south Florida, the northern curly-tailed lizard has expanded its range within the peninsula (see reviews in Wilson and Porras 1983, Butterfield et al. 1997, Bartlett and Bartlett 1999). Wilson and Porras (1983) strongly correlated nonindigenous amphibian and reptile population patchiness

with habitat disturbance in Florida. Northern curly-tailed lizards likewise are frequently found in disturbed habitats associated with anthropogenic structures (i.e., buildings, pavement, parking lots, etc. especially with age-related structural fractures or rubble cover). Such conditions in coastal south Florida provide some elements similar to the type habitat occupied by the species in its endemic West Indian environments (Schwartz and Thomas 1975, Schwartz and Henderson 1991).

Wilson and Porras (1983) also suggested that competition between introduced and indigenous herpetofauna probably was not a major conservation concern. However, Butterfield et al. (1997) considered a conjecture of "shift in habitat usage" by competing anole (*Anolis* spp.) species in Florida and elsewhere. More compelling, Schoener et al. (2002) found that experimental introductions of *L. carinatus* to small tropical islands had immediate major impacts on *A. sagrei* population density and height of perch, and impacts on percentage of hatchlings that survive and body condition followed over a longer time period. Likewise, Callahan (1982:51) in Florida also reported "from 60 to 30 percent fewer brown anoles per transect were in evidence at sites where *L. c. armouri* were active." Callahan concluded (1982:ix) . . . "the brown anole (*Anolis sagrei*), has undergone a population reduction in areas where *L. c. armouri* have become established. *Anolis sagrei* has apparently shifted its activity to more arboreal portions of the habitat." The combined study ranges of Callahan (1982) and Smith et al. (2004), are also inhabited by the green anole (*A. carolinensis*), six-lined racerunner (*Cnemidophorus sexlineatus*), southeastern five-lined skink (*Eumeces inexpectatus*), and in some places the Florida scrub lizard (*Sceloporus woodi*). Consequently, it is reasonable to speculate that native lizards have been, or will be, impacted by northern curly-tailed lizards within their expanding Florida coastal peninsula and barrier island range. For this reason, the impacts of this species on Florida's native lizards and other fauna warrant examination in concert with documentation of its geographic range changes.

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