Florida Park Service
2003 "Parknership" Technical Report

A REVIEW OF THE RANGE, DISTRIBUTION, AND ECOLOGY OF THE INVASIVE NORTHERN CURLY-TAILED LIZARD IN FLORIDA

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Abstract. We examined the distribution and ecology of the exotic northern curly-tailed lizard (*Leiocephalus carinatus armouri*) in Florida. Published literature and especially unpublished documents and data were reviewed and synthesized. Our findings suggest that both the range and distribution of the Florida population have expanded at a rapid rate during the last 60 years. Ecological effects of this species on Florida's native lizards and other fauna have not been quantified and require thorough evaluation.

Key words: behavior; competition; distribution; ecology; exotic lizard; Florida; Leiocephalus carinatus armouri*; northern curly-tailed lizard; range.*

INTRODUCTION, RANGE AND DISTRIBUTION

Palm Beach County and Martin County

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). Duellman and Schwartz (1958) reported the species as an introduced exotic in Palm Beach County, Florida. The 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 population 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 farther 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 unpubl. thesis). By 1981, northern curly-tailed lizards also were established on the mainland at the Southern Boulevard Bridge and Lake Avenue Bridge approaches (Callahan unpubl. thesis). Smith and Engeman (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). In 2002, they were found to be common in an allopatric population at Belle Glade, on the eastern side of Lake Okeechobee (K.L. Krysko pers. comm.). A population was discovered in John D. MacArthur Beach State Park, North Palm Beach, in September 2003 (HTS pers. observ.).

Northern curly-tailed lizards now have been reported to the north in Martin County (Hauge and Butterfield 2000,

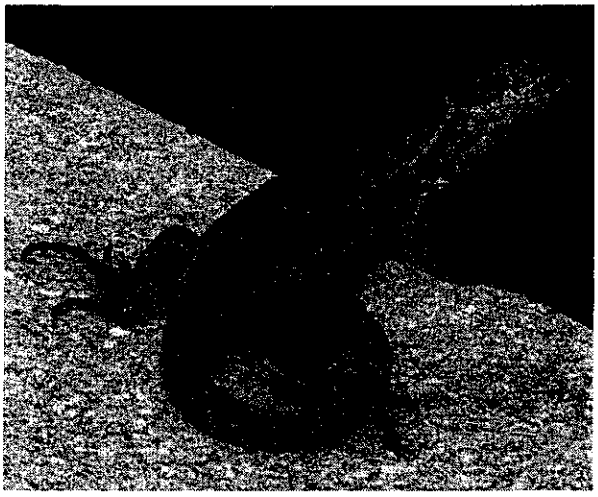

PLATE 1. *Leiocephalus carinatus* at Virginia Key, Florida, 26 August 2003. Image by E. Golden, FPS.

Smith and Engeman 2002, Smith et al. in press[a], Smith et al. in press[b], Dean et al. in review), which rests on the northern border of Palm Beach County. A recent survey of this 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. in press[b]). 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 and E. Cowan, Florida Dept. Environmental Protection, pers. observ.).

Callahan (unpubl. thesis) calculated the range expansion area of the Island of Palm Beach population from 1945-1981 as averaging 50.0 ha/yr., and for the Palm Beach County mainland population from 1968-1981 as 84.2 ha/yr. Smith et al. (in press[b]) 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/yr. 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. in press[b]).

A stage two Atlantic coastline survey was conducted September–October 2003 from Hobe Sound northward through Martin County and St. Lucie County to the Indian River County border (H. Smith et al. unpubl. data). A disjunct population was found ca. 11 km north of Hobe Sound in Port Salerno, Martin County (HTS and C.L. Dean unpubl. data) (State Museum of Pennsylvania voucher no. SMP-H2108).

St. Lucie County

During the September–October 2003 survey the first record for St. Lucie County was collected (State Museum of Pennsylvania voucher no. SMP-H2130) near the intersection of U.S. Highway 1 and Prima Vista Boulevard (27°19.601'N, 80°19.369'W) (C.L. Dean and HTS unpubl. data). This location is ca. 23 km north of the Port Salerno site.

Dade County

A second, early population initially 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). The Virginia Key population of *L. c. armouri* at Miami Seaquarium remains quite viable (HTS pers. observ., E. Golden pers. comm.); however, no specimens were observed at Crandon Park during extensive surveys 1995–2003 (K.L. Krysko pers. comm.). An additional population of *L. c. armouri* was discovered in 1982 by D. Wilson at the Port of Miami (Callahan unpubl. thesis), which apparently has been little studied. Bartlett and Bartlett (1999) listed Dade County as being occupied but specific locations were not provided. Conant and Collins (1998) listed 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.). About 30 specimens were recorded from Buttonwood Bay, Key Largo in 2003 (K.L. Krysko pers. comm.). Another disjunct population was found in Florida City, Dade County (Meshaka et al. in press). Individual lizards also have been sporadically reported at a site in Sebastian Inlet State Park at the juncture of Indian River and Brevard counties between 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 ..."I saw 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 my state vehicle at the time I assumed it had hitched a ride with me." Layne (1987) reported a single specimen 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. in press, Smith et al. in press[b]). 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. in press[a], Smith et al. in press[b]), 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. in press[b]). 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.).

Godley et al. (1981), Callahan (unpubl. thesis), Layne (1987), and McCoid (2002) all mention the role of road-

corridors in facilitating the range expansion of exotic lizard populations. On two occasions, 19 May 1999 and 1 March 2003, individual northern curly-tailed lizards were discovered in apartment-complex garbage dumpsters at the Woolbright Road site, precariously perched at the tops of piles of trimmed vegetation which had been disposed of after maintenance landscaping (HTS pers. observ.). As it seemed very unlikely that the lizards could have escaped the dumpsters, and presuming that they survived the trip to the municipal landfill, this could be another possible "jump-dispersal" transport mechanism for range expansion. Likewise, commercial landscapers removing and transporting piles of trimmed vegetation from site to site, in open-bed trailers, as is very common in south Florida, may be contributing to wholesale range expansions of this and other exotic lizards.

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 entire parking lot with molten liquid tar during late April 2003 resulted in very high lizard mortality (HTS pers. observ.).

Natural History, Key Behaviors and Ecological Effects

Callahan (unpubl. thesis) 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. (in press) 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 unpubl. thesis, HTS pers. observ.). Callahan (unpubl. thesis) reported them to be active until early afternoon, then return to rufugia for 30–90 minutes respite before becoming active again until ca. 30 minutes before/after sunset. On cooler November and December days (0 - 10° C) activity starts 60-90 minutes later in the morning and ends 60-90 earlier in the evening (Callahan unpubl. thesis). 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 unpubl. thesis, Meshaka et al. in press, HTS pers. observ.). Meshaka et al. (in press) 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. in press), 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 unpubl. thesis), as well as physical confrontations.

Curly-tailed lizards are carnivorous and capture their prey by sitting and waiting vigilantly, then stalking, or more commonly rushing their prey (Callahan unpubl. thesis, HTS pers. observ.). In Palm Beach County, the cricket (*Gryllus assimilis*) 17.2%, grasshoppers (*Melanoplus spp.*) 10.1%, and isopods 9.7% were reported as the most common food items from 10 adult stomachs by percent total volume (Callahan unpubl. thesis). 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. (in press) likewise reported 60 lizards collected from Palm Beach County consumed mostly beetles (73 stomach items), roaches (*Dictyoptera*) (22), and ants (80), with 11 other taxa also 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 unpubl. thesis, HTS pers. observ.). Callahan (unpubl. thesis) observed two different 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 (unpubl. thesis) concluded that females less than 73 mm 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 (unpubl. thesis) also concluded that oviposition of eggs in Florida occurred in June or early July. Meshaka et al. (in press) 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. in press). Smith et al. (in press[b]) 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 Southern black racer (*Coluber constrictor*) (Callahan unpubl. thesis, Meshaka et al. in press). 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 in press), 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 effects on *A. sagrei* population density and height of perch; and, effects on percentage hatchlings and body condition followed over a longer time period as well as other changes. Likewise, Callahan (unpubl. thesis, pp. 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 (Figure 16, 17, 18)." Callahan concluded (unpubl. thesis, abstract pp. 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 (unpubl. thesis) and that of Smith et al. (in press[b]), are cohabited by the native 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. The effects of this species on Florida's native lizards and other fauna need to be thoroughly examined. Considerable, additional survey effort will be required to document the inland range of this population in Florida.

Acknowledgments

We thank W. Meshaka, The State Museum of Pennsylvania, for the species information from his forthcoming book on the exotic herpetofauna of Florida. K.L. Krysko, Florida Museum of Natural History, graciously shared his unpublished data for Belle Glade, Crandon Park, and Buttonwood Bay. FPS-PBCC "Parknership" student intern C. Dean enthusiastically surveyed Martin and St. Lucie counties September–October 2003. We also thank R. Johns (FDEP), M. Nelson (FDEP), S. O'Neal (FDEP), E. Golden (FDEP), E. Cowan (FDEP), and J. Walsh (FFWCC) for providing observation data. E. Golden provided the high-quality image. P. Moler (FFWCC) provided a helpful review of an earlier draft of the manuscript.

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SUGGESTED CITATION FOR THIS REPORT

Smith, H.T., and R.M. Engeman. 2003. A Review of the Range, Distribution, and Ecology of the Invasive Northern Curly-tailed Lizard in Florida. Florida Park Service "*Parknership*" Technical Report. 5 pp.