

Anoline Succession Follows Habitat Succession at the Barnacle Historic State Park in Southern Florida

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Abstract- Standardized surveys of diurnal lizards were conducted at the Barnacle Historic State Park (BHSP) in the Coconut Grove neighborhood of Miami, Miami-Dade County, Florida, in 2007 and 2020. During the initial survey, the Brown Anole, *Anolis sagrei*, comprised 54.6% and 81.6% of lizards seen at two survey routes, outnumbering the Puerto Rican Crested Anole, *A. cristatellus*, 2.72:1.00. In 2020, 70 individuals of *A. cristatellus* and a single male *A. sagrei* were encountered. Combined search time for all sites during each of the two surveys revealed a change from 2.69 times as many *A. sagrei* to a system supporting 69 times more *A. cristatellus* per unit time than its erstwhile dominant congener. Furthermore, encountered as often as 1.71 individuals/minute, *A. cristatellus* exploited lower perch heights more so in 2020 than when outnumbered in 2007 by *A. sagrei* whose perch heights were predominantly close to the ground. With a presumed competitive edge over *A. sagrei* in shaded habitats, *A. cristatellus* colonies such that of BHSP are not surprisingly successful. However, like the hammocks themselves, extensive loss of canopy through human activities or hurricanes could revert this site to the pine-land it once was with a return of *A. sagrei*.

Introduction

The Barnacle Historic State Park (BHSP) is a 2.0 ha park located at 3485 Main Highway in the Coconut Grove neighborhood of Miami, Miami-Dade County, Florida (Figure 1). Originally part of a 16.2 ha bayfront parcel overlooking Biscayne Bay that was purchased by Ralph Middleton Munroe in 1886, what is now the BHSP with the house and boathouse was purchased by the Florida Park Ser-

vice from Munroe's descendants in 1973.

A herpetofaunal bioblitz was conducted at the BHSP in 2005 (Meshaka et al., 2008) at which time seven new exotic species and two new native species were added to the list of resident species bringing a total of 10 exotic species and eight native species (Meshaka et al., 2008). At the time of the bioblitz, the Brown Anole, *Anolis sagrei*, was primarily seen on vegetation near and on walls. The Puerto Rican Crested Anole, *A. cristatellus*, was found primarily in the hammock which extended 0.19 km southeast from the entrance to the park. On 6 July 2007 and 14 February 2020, timed surveys were conducted in portions of the park for diurnally-active lizards. Of primary interest to us was the status of diurnal anoles, especially *A. sagrei* (Figure 2), *A. cristatellus* (Figure 3), the Cuban Green Anole, *A. porcatius* (Figure 4), and the Bark Anole, *A. distichus*, whose activity could be expected in the dry season.

Materials and Methods

The Barnacle Historic State Park (BHSP) is a 2.0 ha public park overlooking Biscayne Bay (Figure 1), 3485 Main Highway in the Coconut Grove neighborhood of Miami, Miami-Dade County, Florida (25°43'30"N 80°14'32"W). Rectangular in shape, the northwest corner provides the main entrance along Main Highway, and the park is bordered by cement walls and vegetation leading southeasterly toward the ocean. A winding stone trail leading from the entrance to the parking lot and office bisects a tropical hardwood hammock with remnant pine trees. The remaining portion of the park is sod, formerly dune, upon which rests the two-story house, and near the bay, a yellow boathouse.

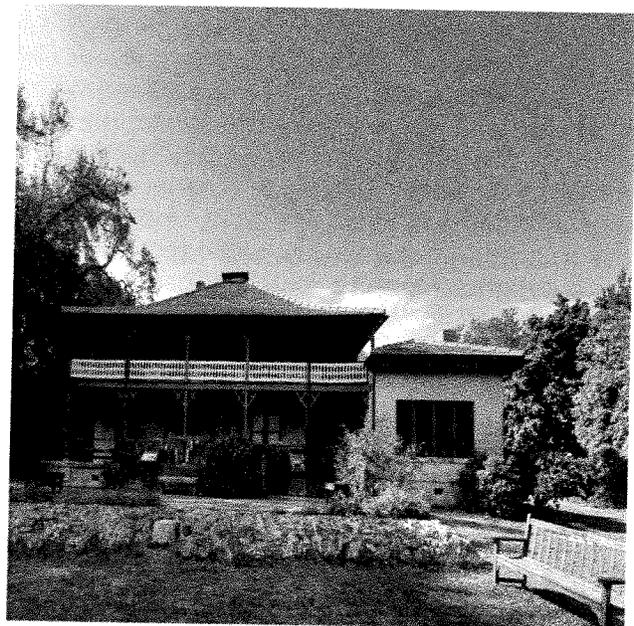


Figure 1. Survey sites at the Barnacle Historic State Park, Miami, Miami-Dade County, Florida, on 14 February 2020. Left Wall and Right Wall (A), Boathouse (B), Hammock Right and Hammock Left (C), and Main House (D). Photographs by W.E. Meshaka, Jr.

B

D

The first diurnal survey was conducted on 6 July 2007. Portions of the park along the northeastern wall and the entrance, and waterfront were surveyed during 1050–1140 hrs. The trail leading from the office to the main gate was surveyed during 1150–1210 hrs. Perch heights were recorded as follows: 0.00–0.50 m, 0.50–1.00 m, 1.00–1.50 m, >1.50 m. The second diurnal survey was conducted on 14 February 2020 during 1410–1540 hrs at six sites:

Left Wall (Figure 1a) refers to the transect along the northeast wall and adjacent vegetation from the parking lot to the water surveyed during 1410–1424 hrs. Distance was approximately 165.5 m. Right Wall (Figure 1a) refers to the transect along the southwest wall and adjacent vegetation from the water to the parking lot surveyed during 1430–1436 hrs. Distance was approximately 165.5 m. Boat-house (Figure 1b) refers to the two-story structure located along the shoreline. Search time was one minute during each of two surveys of 1425–1426 hrs when cloudy and 1539–1540 hrs when sunny. Hammock Right (Figure 1c) refers to the transect following the stone trail from the office to the main gate along which lizards were counted on the right side of the trail to 2 m into the hammock. Hammock Right was surveyed during 1440–1447 hrs. Distance was approximately 214 m. Hammock Left (Figure 1c) refers to the transect following the stone trail from the main gate to the office along which lizards were counted on the left side of the trail to 2 m into the hammock. Hammock Left was surveyed during 1447–1459 hrs. Distance was approximately 214 m. Main House (Figure 1d) refers to the historic residence situated between the parking lot and the waterfront and was surveyed during 1521–1527 hrs.

Perch heights of the 2020 survey were recorded as follows: 0.00–0.60 cm, 0.60–1.05 cm, 1.05–1.80 cm, >1.80 cm. Cloud cover ranged from partial sun to sultry. Local air temperature ranged 79–82 F. Pearson's χ^2 test was used for count data as part of the native stats package in R (R Core Team 2019) to test whether or not there was an association between the distribution of species at different sampling periods and at different heights in their habitats. Absence of support for an association would indicate that the relative abundance of the two lizards has undergone a significant change over the years of sampling and/or at different levels of the vegetation. In cases where sample sizes were too small

to reliably meet the approximation of a normal distribution required for the χ^2 test, we used Fisher's exact test for count data. We assigned a nominal significance level of $p < 0.05$.

Results and Discussion

Assemblage structure 2007 v 2020- In 2007, *A. sagrei* was the dominant lizard, comprising 69.01% of all diurnal lizard sightings from the combined sites and was dominant in both survey sites (Table 1). During that survey, *A. cristatellus* comprised 25.35% of all lizard sightings. Congeneric species and the Wood Slave, *Hemidactylus mabouia*, were marginal in detection (Table 1). *Anolis cristatellus* comprised 92.86% of the 70 individual lizards encountered during the 2020 survey and was the dominant lizard at all survey sites (Table 2). Among its congeners, only a single adult male *A. sagrei* (1.43%) (Figure 2) and two *A. porcatus* (Figure 4) were detected that day (Table 1). *Leiocephalus carinatus*, a recent colonizer, was seen at the Boathouse and the Main House (Figure 1b).

Relative abundance 2007 v 2020- Encounter rates as measured by no. lizards observed/ minute was highest in *A. sagrei*, and especially so in the hammock during the 2007 survey ($\chi^2 = 72.5$, $p < 2.2e-16$) (Table 3). In 2020, *A. cristatellus* greatly exceeded encounter rates of all species at all sites, especially the well-shaded left wall and the hammock (Table 4).

Perch height 2007 v 2020- The distribution of perch heights of *A. cristatellus* and *A. sagrei* differed significantly from one another in 2007 (Fisher's Exact Test for Count Data, $\chi^2 = 9.05$, $P = 0.022$), whereby *A. sagrei* differentially occupied lower perches than did invading *A. cristatellus* (Figure 5). Distribution of perch heights by *A. cristatellus* in 2020 were significantly different (Fisher's Exact Test for Count Data, $\chi^2 = 19.77$, $P = 0.00014$) than that of *A. cristatellus* in 2007, whereby those in 2020 differentially occupied lower perches than conspecifics in 2007 (Figure 5). A comparison of perch height distribution between *A. cristatellus* in 2020 with that of *A. sagrei* in 2007 detected no significant difference (Fisher's Exact Test for Count Data, $\chi^2 = 4.76$, $P = 0.20$; (Figure 5). These analyses indicate that colonizing *A. cristatellus* did not occupy favored perches until *A. sagrei* was gone (Figure 6). To that end, both species favor lower perches at the Doc Thomas House, where *A.*

sagrei is relegated primarily to a sunny edge of the property (Meshaka et al., 2008). Lower perch heights were also favored by *A. sagrei* at the Doc Thomas House before Post-Hurricane Andrew canopy development and subsequent colonization of *A. cristatellus* (Meshaka, 1999).

Herpetofaunal species list 2007 v 2020-

Since the herpetofaunal bioblitz of 2005 (Meshaka et al., 2008), only one new exotic species, *L. carinatus*, appears to have colonized the BHSP (Table 5). First seen in 2014 (Jessica Cabral, pers. Comm.), this species is well established around buildings on the property, where it has demonstrated an ability to negatively impact the Everglades Racer, *Coluber constrictor paludicola* (Figure 7). We do not know the extent of this lizard's range in Coconut Grove. Although both *A. cristatellus* and *A. sagrei* remain on the species list for the BHSP, their distributions have shifted profoundly during the intervening years of the surveys. As in the case of *L. carinatus*, we do not know the extent to which *A. cristatellus* has colonized Coconut Grove nor do we know the relative abundances of these two anoles. During our 2020 survey, we photographed what we believe to be a hybrid between *A. cristatellus* and *A. sagrei* (Figure 8). If this lizard represents a hybrid, then the demise of *A. sagrei* on the BHSP can be primarily attributed to superior competitive ability by *A. cristatellus* in canopied habitat and secondarily by hybridization to some extent with remaining individuals of *A. sagrei*. Presumably, hurricane-mediated opening of the canopy on the property will serve as a selective pressure favoring a reversal of this assemblage structure and the habitat itself back to rockland pine. The remaining anoles could actually benefit in this scenario depending on the extent to which the canopy were to open.

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Figure 2. A male *Anolis sagrei* from the Barnacle Historic State Park, Miami, Miami-Dade County, Florida, on 14 February 2020. Photograph by W.E. Meshaka, Jr.

Table 1. No. of individuals of each of five diurnally-active lizard species expressed as a percentage of all individuals of all five species seen at each site at the Barnacle Historic State Park, Miami, Miami-Dade County, Florida, on 6 July 2007.

Species	Fence sites	Hammock
<i>A. carolinensis</i>	3.03030303	0
<i>A. cristatellus</i>	33.33333333	18.42105263
<i>A. equestris</i>	3.03030303	0
<i>A. sagrei</i>	54.54545455	81.57894737
<i>H. mabouia</i>	6.060606061	0
Percent total	100	100
N	33	38

Table 2. No. of individuals of each of four diurnally-active lizard species expressed as a percentage of all individuals of all four species seen at each site at the Barnacle Historic State Park, Miami, Miami-Dade County, Florida, on 14 February 2020.

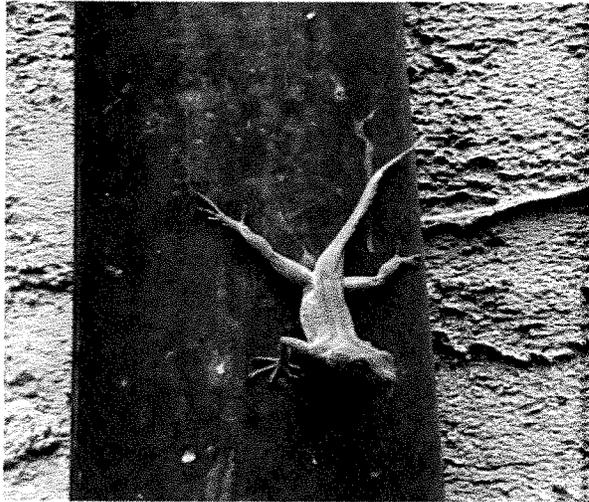
Left side from parking to water	Left			Right Wall	Main House	Hammock Right	Hammock Left
	Wall	Boathouse	Boathouse				
<i>A. cristatellus</i>	89.47	66.67	100	80	92.31	100	100
<i>A. sagrei</i>	0	0	0	20	0	0	0
<i>A. porcatus</i>	10.53	0	0	0	0	0	0
<i>L. carinatus</i>	0	33.33	0	0	7.69	0	0
Percent total	100	100	100	100	100	100	100
N	19	3	3	5	13	12	15

Table 3. No. of individuals seen per minute search time of four diurnally active lizards at the Barnacle Historic State Park, Miami, Miami-Dade County, Florida, on 6 July 2007.

Species	Fences	Hammock	Combined sites
<i>A. carolinensis</i>	0.02	0	0.0143
<i>A. cristatellus</i>	0.22	0.35	0.2571
<i>A. equestris</i>	0.02	0	0.0143
<i>A. sagrei</i>	0.36	1.55	0.7
<i>H. mabouia</i>	0.04	0	0.0286
N	50	38	71



A

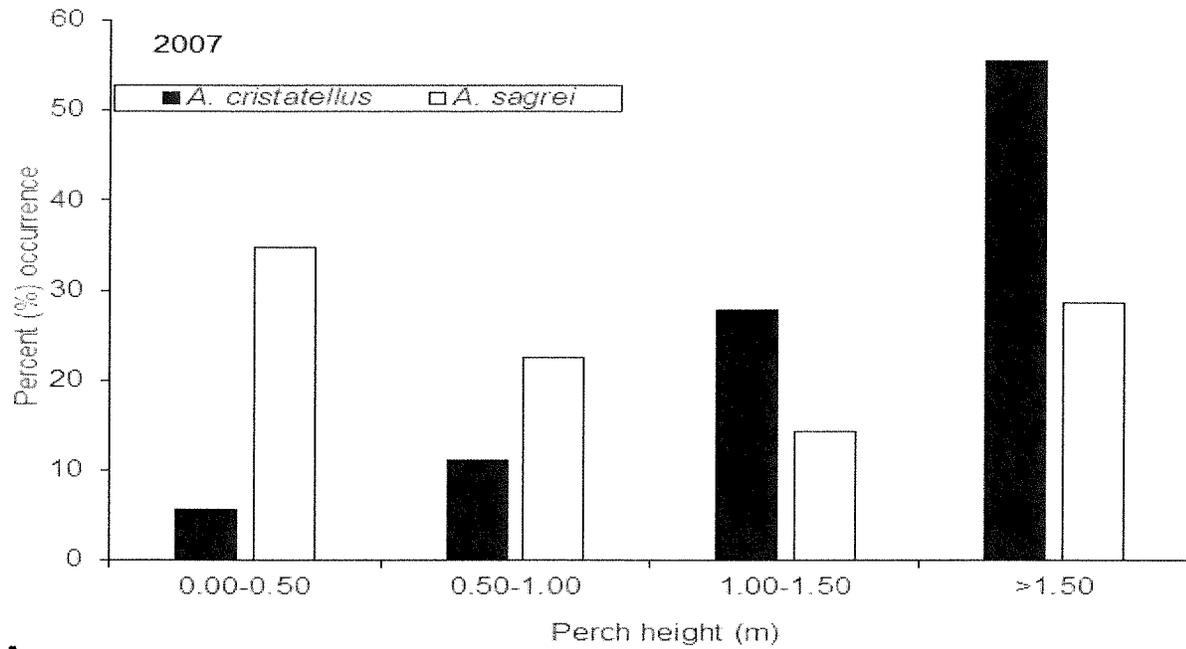


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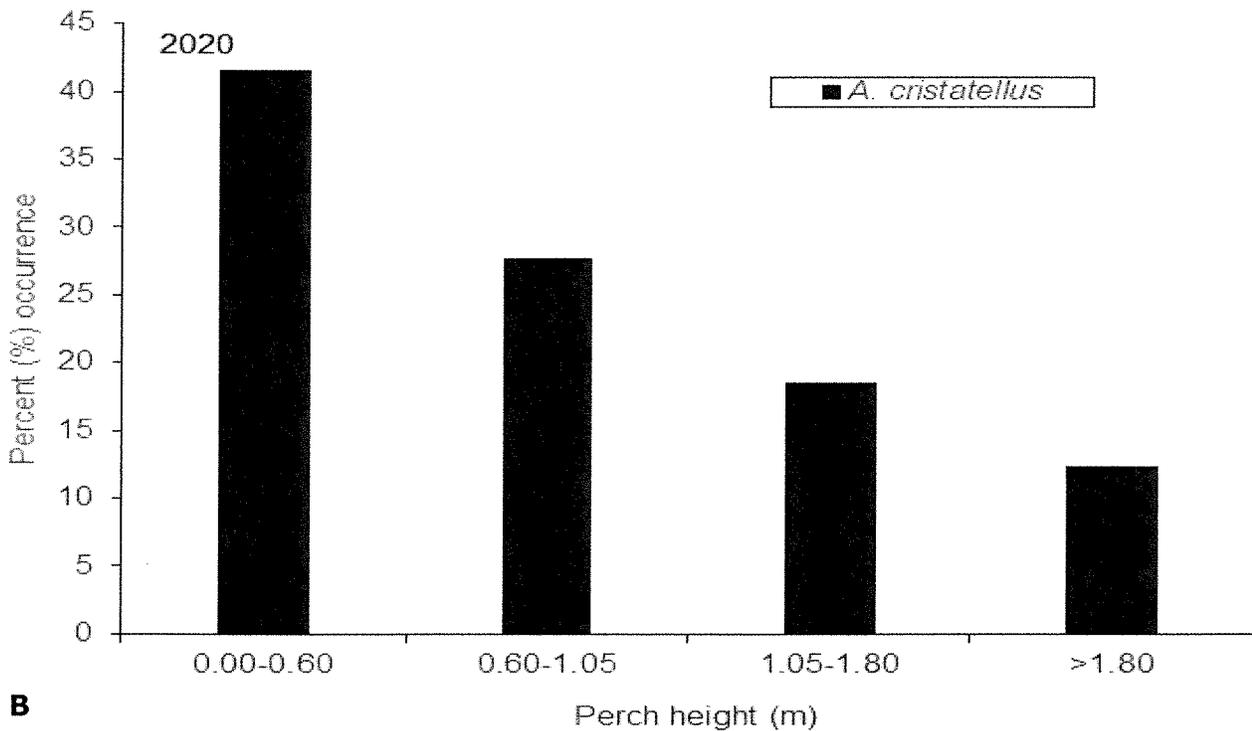
Figure 3. Two males of *Anolis cristatellus* (A and B) from the Barnacle Historic State Park, Miami, Miami-Dade County, Florida, on 14 February 2020. Photographs by W.E. Meshaka, Jr.



Figure 4. A male *Anolis porcatus* from the Barnacle Historic State Park, Miami, Miami-Dade County, Florida, on 14 February 2020. Photograph by W.E. Meshaka, Jr.



A



B

Figure 5. Perch heights in m of *Anolis cristatellus* and *A. sagrei*, on 6 July 2007 (A) and *A. cristatellus* on 14 February 2020 (B) at the Barnacle Historic State Park, Miami, Miami-Dade County, Florida.



Figure 6 Two adults of *Anolis cristatellus* in the tropical hardwood hammock of the Barnacle Historic State Park, Miami, Miami-Dade County, Florida, on 14 February 2020. Pho-



Figure 8. A suspected hybrid of *Anolis cristatellus* X *A. sagrei* from the Barnacle Historic State Park, Miami, Miami-Dade County, Florida, on 14 February 2020. Photograph by W.E. Meshaka, Jr.



Figure 7. Predation by *Leiocephalus carinatus* on *Coluber constrictor paludicola* at the Barnacle Historic State Park, Miami, Miami-Dade County, Florida. Photograph by Jessica Cabral.

Table 4. No. of individuals seen per minute search time of four diurnally active lizards at the Barnacle Historic State Park, Miami, Miami-Dade County, Florida, on 14 February 2020.

Site	<i>A. cristatellus</i>	<i>A. sagrei</i>	<i>A. porcatius</i>	<i>L. carinatus</i>	Total
Left Wall	1.21	0	0.14	0	1.36
Boathouse	2.0	0	0	1.0	3.0
Boathouse	3.0	0	0	0	3.0
Right Wall	0.67	0.17	0	0	0.83
Main House	2	0	0	0.17	2.17
Hammock Right	1.71	0	0	0	1.71
Hammock Left	1.25	0	0	0	1.25
Totals	1.38	0.02	0.04	0.04	1.49

Table 5. Amphibian and reptile species documented from the Barnacle Historic St Park, Miami, Miami-Dade County, Florida. * = exotic species.

Amphibians

Greenhouse Frog*	<i>Eleutherodactylus planirostris</i>
Green Treefrog	<i>Hyla cinerea</i>
Squirrel Treefrog	<i>H. squirella</i>
Cuban Treefrog*	<i>Osteopilus septentrionalis</i>

Lizards

Green anole	<i>Anolis carolinensis carolinensis</i>
Puerto Rican Crested Anole*	<i>A. cristatellus</i>
Bark Anole*	<i>A. distichus</i>
Knight Anole*	<i>A. equestris equestris</i>
Cuban Green Anole*	<i>A. porcatius</i>
Brown Anole*	<i>A. sagrei</i>
Eastern Six-lined Racerunner	<i>Aspidoscelis sexlineata sexlineata</i>
Indo-Pacific Gecko*	<i>Hemidactylus garnotii</i>
Wood Slave*	<i>H. mabouia</i>
Green Iguana*	<i>Iguana iguana</i>
Northern Curly-tailed Lizard*	<i>Leiocephalus carinatus</i>
Southeastern Five-lined Skink*	<i>Plestiodon inexpectatus</i>
Reef Gecko*	<i>Sphaerodactylus notatus</i>

Snakes

Everglades Racer	<i>Coluber constrictor paludicola</i>
Southern Ring-necked Snake	<i>Diadophis punctatus punctatus</i>
Brahminy Blindsnake*	<i>Indotyphlops braminus</i>
Red Cornsnake	<i>Pantherophis guttatus</i>
Yellow Ratsnake	<i>Pantherophis obsoletus quadrivittatus</i>
Rim Rock Crowned Snake	<i>Tantilla oolitica</i>

Turtles

Loggerhead Sea Turtle	<i>Caretta caretta</i>
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