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Invasive *Anolis sagrei* on St. Vincent and Its Potential Impact on Perch Heights of *Anolis trinitatis*

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ABSTRACT.—The lizard genus *Anolis* (Polychrotidae) is essentially ubiquitous in the West Indies, with most species confined to one island bank. However, human-mediated transport of materials, plants, and animals has introduced species across natural boundaries, sometimes with deleterious effects on native anoles. Among the most recent introductions is *Anolis sagrei* on St. Vincent. We investigated the distribution of introduced populations and evaluated possible effects on perch heights of native anoles (*A. griseus* and *A. trinitatis*) at a site where all three species occur. We found little evidence that *A. sagrei* has affected either native species. Perch heights of *A. trinitatis* in the presence of *A. sagrei* were comparable to those found in habitats where *A. sagrei* did not occur. However, we suggest continued monitoring of this exotic on St. Vincent to evaluate potential long-term impact on native species and to

determine whether any effects will extend beyond heavily altered low-elevation sites.

Keywords.—*Anolis griseus*, *Anolis sagrei*, *Anolis trinitatis*, invasive, St. Vincent

Anolis sagrei (Polychrotidae) is a moderately sized anole (maximum snout-vent length [SVL] to 70 mm in males and 50 mm in females; Schwartz and Henderson 1991) native to Cuba, the Bahamas, Little Cayman, and Cayman Brac. It prefers sunny habitat with low perches (ground-level or just above) and does well in suburban areas (Schoener 1968; Schwartz and Henderson 1991).

Introductions of *A. sagrei* have been documented in the southeastern United States (see summary in Lever 2003), along the Caribbean coasts of Mexico and Belize (Lever 2003), and on Jamaica (Williams 1969), Bermuda and Grand Cayman (Losos et al. 1993), Grenada (Greene et al. 2002), Hawaii (e.g., McKeown 1996; Goldberg and Bursey 2000; Muensch et al. 2006), and Taiwan (Norval et al. 2002). More recently, Henderson and Powell (2005) noted the presence of *A. sagrei* on St. Vincent. The success of *A. sagrei* as an invader was demonstrated further by Losos and Spiller (1999) on Bahamian islands, where experimental founder populations of only five individuals flourished. Also, individuals in introduced populations often are larger than in areas where the species is native, which is suggestive of ecological release (Campbell and Echternacht 2003) or admixture of evolutionarily distinct groups (Kolbe et al. 2007).

Anolis sagrei may be one of the most successful anoline invasives. It has largely displaced native *A. carolinensis* throughout much of Florida (e.g., Campbell 2000), with much of this effect attributable to intraguild predation (Campbell and Gerber 1996; Gerber and Echternacht 2000). On Grand Cayman, the introduction of *A. sagrei* altered the spatial ecology of native *A. conspersus* (Losos et al. 1993), forcing the latter to utilize higher perches. In contrast, on Grenada, Greene et al. (2002), based solely on habitat preferences without quantitative data, speculated that the presence of *A. sagrei* would have little effect on native anoles. However, Powell and Henderson (2005) stated that the long-term effects of introduced anoles on congeners often are unpredictable.

Based on its recent discovery and restricted distribution, *Anolis sagrei* presumably arrived on St. Vincent only two to three years ago, which may be too short of a time span for it to have had any observable population level effects on either endemic congener. *Anolis griseus* is a much larger species (maximum SVL = 136 mm in males, 86 mm in females) and generally uses high perches (2-8 m) in large trees (Schwartz and Henderson 1991). However, *A. trinitatis* is comparable in size (male SVL to 74 mm in males and 57 mm in females)

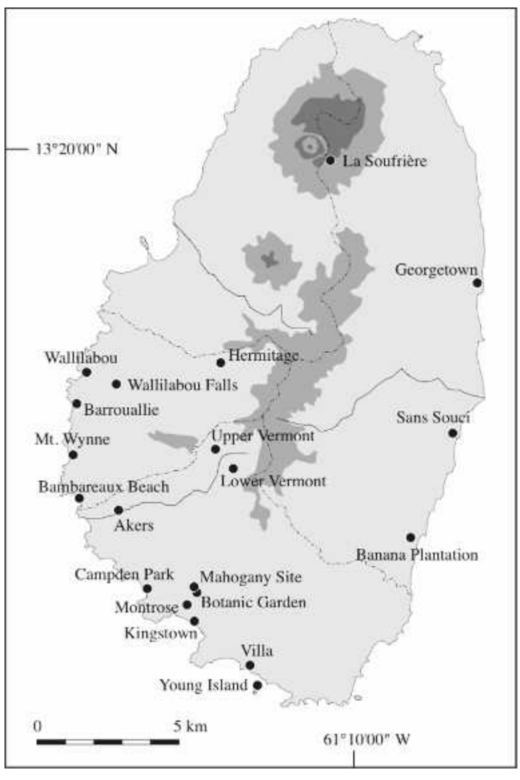

FIG. 1. Map of St. Vincent indicating all sites where concurrent diurnal studies occurred. *Anolis sagrei* was only observed in Campden Park, the Montrose area, and Kingstown.

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to *A. sagrei* and generally utilizes low perches (<2 m high; Schwartz and Henderson 1991), increasing the likelihood of competition with *A. sagrei* in areas of sympatry (e.g., Losos et al. 1993).

From 1-21 June 2006, we searched visually for *A. sagrei* at various locations in urban, relatively natural, and altered agricultural areas across St. Vincent (Figure 1). After confirming that each of two observers used comparable methods, we also examined habitat use by *A. sagrei* and the two endemic species at a heavily altered low-elevation (<100 m above sea level) construction site in the Montrose neighborhood, where we conducted timed surveys along a 145-m transect twice each hour from 0600-1800 h, recording species, size class, and perch characteristics for each sighting. Size classes for *A. sagrei* and *A. trinitatis* were defined as: 1 = adult males (>50 mm SVL), 2 = subadult males/adult females (~30-50 mm SVL) and 3 = juveniles and hatchlings (<30 mm SVL). Perch heights were recorded to the nearest 5 cm based on measurements made at the beginning of the investigation. Natural perches were characterized as: 1 = natural substrate (e.g., soil and grasses) and low vegetation, 2 = saplings, and 3 = large fruit trees; and artificial perches as: 4 = peripheral concrete block walls and foundation, and 5 = miscellaneous construction materials (e.g., boards and piles of concrete blocks). Because anoles might be affected by observers (Sugerman 1990), we did not capture any, nor did we record data for moving individuals if an initial position was not observed.

We used repeated measures (RM) ANOVA to compare perch heights between the different size classes of *A. sagrei* and *A. trinitatis* (observations of *A. griseus* were too few for statistical analyses) and to compare perch heights between each and all size classes of both species, Kruskal-Wallis tests to examine variation in perch heights at different times of day, and chi-square tests to evaluate differences in the proportions of *A. sagrei* and *A. trinitatis* on different perch types. Statistical analyses were performed with StatView 5.0 (SAS Institute Inc., Cary, North Carolina). Means are presented ± 1 SE; $\alpha = 0.05$.

We found *A. sagrei* along the rocky edge of the deepwater wharf in Kingstown and in similar habitat at Campden Park, the probable sites of its initial introduction onto the island (Henderson and Powell 2005; Figure 2). Both sites are characterized by large boulder riprap, used to stabilize the coastlines. In Kingstown, the population extended from the pier area across a road into open fields, but no individuals were found more than 50 m from the coast. Along the water, we found *A. sagrei* from the southeastern edge of the main pier to 1115 m west, near the ridge between Edinboro and Victoria Park. At Campden Park, *A. sagrei* occurred along the coastal riprap of the shipping port and 400 m inland along a main road. Lizards were found along the coast extending from the dock, which bordered the southern ridge in the Lowman area to 550 m north near a ridge at Questelles. Lizards were seen on the ground, on fences, and on palm trees (*Cocos nucifera*). Two other disjunct populations were discovered at or near construction sites in the Montrose neighborhood, where lizards were observed primarily on low perches (< 1 m), but neither population extended across the major road linking Kingstown with the leeward coast.

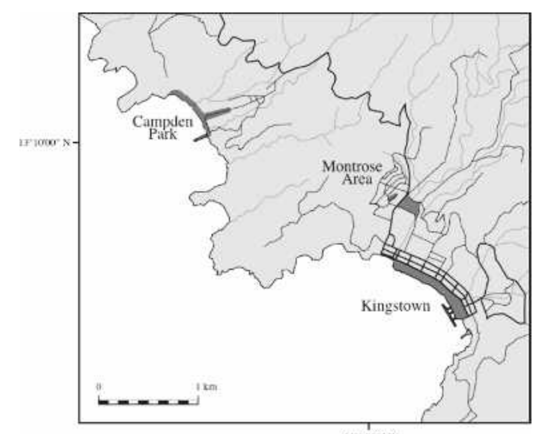

FIG. 2. Map of Kingstown and surrounding area with locations where the presence of *Anolis sagrei* is indicated by dark gray shading. Black lines are roads and gray lines are rivers.

In our habitat-use study in the Montrose neighborhood, we recorded 799, 127, and 6 observations of perch heights and types for *A. trinitatis*, *A. sagrei*, and *A. griseus*, respectively, many of which were undoubtedly repeated observations of the same individuals. Because of small sample size, we excluded *A. griseus* from statistical analyses, but observed individuals were primarily on Mango (*Mangifera indica*) and Breadfruit (*Artocarpus altilis*) trees (one was on a wall), and perch heights ranged from 130-225 cm. We witnessed no interspecific interactions.

Anolis trinitatis perched significantly higher than *A. sagrei* (RM ANOVA, df = 1, $F = 20.49$, $P < 0.0001$; Table 1). Perch heights for size classes of *A. sagrei* (df = 2, $F = 14.31$, $P < 0.0001$) and *A. trinitatis* (df = 2, $F = 7.69$, $P = 0.001$) varied significantly. Perch heights for all *A. trinitatis* varied significantly by time of day (Kruskal-Wallis Test, df = 11, $H = 68.06$, $P < 0.0001$; Figure 3), but those for all *A. sagrei* did not (df = 11, $H = 8.05$, $P = 0.71$). When broken down by size class, perch heights for all size classes of *A. sagrei* (class 1: df = 10, $H = 6.81$, $P = 0.74$; class 2: df = 11, $H = 11.73$, $P = 0.38$; class 3: df = 11, $H = 7.37$, $P = 0.77$, $N = 55$) and for juvenile *A. trinitatis* (df = 11, $H = 9.21$, $P = 0.51$) did not vary significantly throughout the day, but those for larger size classes of *A. trinitatis* (class 1: df = 11, $H = 29.06$, $P = 0.002$; class 2: df = 11, $H = 41.32$, $P < 0.0001$) did. *Anolis sagrei* and *A. trinitatis* differed significantly in types of perches used (df = 5, $\chi^2 = 123.76$, $P < 0.0001$; Table 2) and in the use of natural versus artificial perches (df = 1, $\chi^2 = 32.00$, $P < 0.0001$). *Anolis sagrei* was recorded primarily on artificial substrates, whereas *A. trinitatis* used both natural and artificial perches.

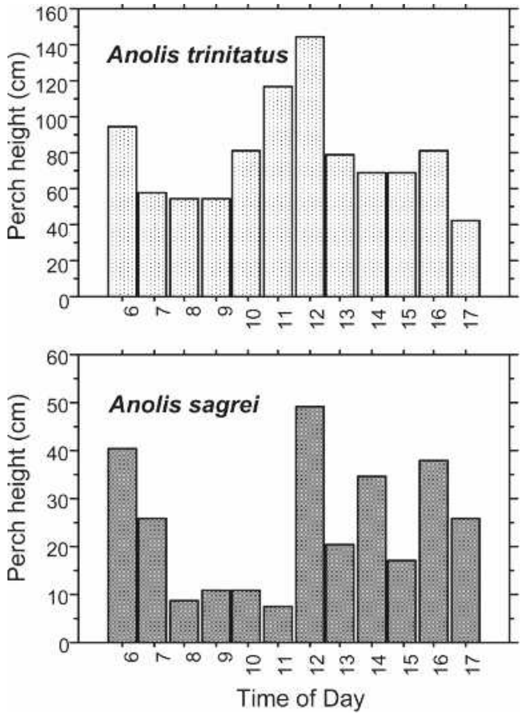

FIG. 3. Mean perch heights of *Anolis trinitatis* and *A. sagrei* at a construction site in the Montrose neighborhood of Kingstown, St. Vincent and the Grenadines. Each bar represents the mean perch height for all size classes of anoles observed during a one-hour period over the course of this study. *Anolis trinitatis* perched significantly higher than *A. sagrei* (note the differing scales in the two graphs).

Our distributional data are similar to those reported for *A. sagrei* on Grenada (Greene et al. 2002), where the species presumably arrived on the island with shipments of lumber, likely from the United

TABLE 1. Mean perch heights ± one SE (cm) of anoles at a construction site in the Montrose neighborhood of Kingstown, St. Vincent. *Anolis sagrei* in all size classes and all individuals perched significantly lower than *A. trinitatis*. Size Class 1 = Adult males; 2 = subadult males and adult females; 3 = juveniles and hatchlings.

	Size class			
Species	1	2	3	All
A. griseus	176.2 ± 21.9 (130-225)	145.0 ± 5.0 (140-150)	—	165.8 ± 15.4 (130-225)
	4	2	—	6
A. sagrei	55.0 ± 9.6 (0-200)	19.9 ± 5.2 (0-140)	5.3 ± 1.0 (0-30)	23.6 ± 3.6 (0-200)
	35	40	52	127
A. trinitatis	110.7 ± 6.2 (0-600)	54.5 ± 3.2 (0-400)	57.9 ± 7.9 (0-450)	74.3 ± 3.0 (0-600)
	275	421	103	799

TABLE 2. Perches used by anoles at a construction site in the Montrose Area of Kingstown, St. Vincent.

	Perches				
	Natural			Artificial	
Species	1	2	3	4	5
A. griseus					
Class 1	—	—	3	1	—
Class 2	—	—	2	—	—
Class 3	—	—	—	—	—
Total	—	—	5	1	—
A. sagrei					
Class 1	1	—	—	23	11
Class 2	4	—	3	18	15
Class 3	11	1	1	19	20
Total	16	1	4	60	46
A. trinitatis					
Class 1	6	17	108	99	45
Class 2	38	18	106	183	76
Class 3	26	6	18	26	10
Total	70	41	232	325	131

1 = Natural, ground-level substrate and vegetation; 2 = saplings; 3 = large fruit trees; 4 = fence-walls and foundation; 6 = miscellaneous loose construction materials (e.g., boards and concrete blocks).

States, and became established at various locations as a consequence of intra-island transport of building materials. Although lumberyards in St. Vincent are enclosed and provided poor habitat for heliophilic lizards (Schwartz and Henderson, 1991), we did find *A. sagrei* along piers, where lumber and other building materials are off-loaded from ships, and around construction sites, where these materials have been transported.

Assuming local dispersal with building materials, the populations of *A. sagrei* in the Montrose neighborhood might be examples of jump dispersal, also observed for *A. sagrei* in Florida and Georgia (Campbell 1996). Also, major roads with heavy vehicular traffic may present effective barriers to active dispersal (e.g., Gilbert, 1989; Forman and Alexander, 1998; Spellerberg, 1998), preventing the further expansion of *A. sagrei* into areas surrounding sites of initial colonization.

That *A. trinitatis* perched higher than *A. sagrei* was not surprising, and corresponded to data generated by earlier studies of these species (Schwartz and Henderson 1991). Also, that perch heights of *A. trinitatis* varied in the course of a day was not unexpected, as some perches presumably would be less attractive during the heat of the day. The lack of significant variation in perch heights of *A. sagrei* and juvenile *A. trinitatis* probably reflects the more limited range of perch heights exploited at any time.

Hite et al. (2008) showed that *A. trinitatis*, in the absence of *A. sagrei*, used perches that varied in height according to the vegetative structure at eight different sites. Mean perch height for all age classes at all sites (114.5 ± 2.5 cm, range = 0-660 cm, N = 1785) and by site (65.9 ± 5.6 to 143.6 ± 5.8 cm) varied considerably. Where habitats had been affected by human activity and available perch heights were most like those at the Montrose site, *A. trinitatis* used perches comparable to those used at our site. Because none of the sites sampled by Hite et al. (2008) were as heavily disturbed as the Montrose construction site, we cannot say whether our observations suggest that *A. sagrei* may be causing *A. trinitatis* to perch higher, similar to the forced habitat shift of *A. conspersus* by *A. sagrei* on Grand Cayman (Losos et al. 1993), or whether the higher perches we observed are merely characteristic of habitat use by this species. However, because *A. sagrei* exhibits intraguild predation, feeding on native anoles where it has been introduced (Campbell and Gerber 1996; Gerber and Echternacht 2000), especially adult male *A. sagrei* might prey on juvenile and hatchling *A. trinitatis*. Mean perch heights reported by Hite et al. (2008) for the smallest size class (< 40 mm SVL) at eight sites varied from 17.3 ± 3.6 to 115.3 ± 15.6 cm (N = 748), with ranges that fell within or overlapped considerably with those used by adult male *A. sagrei* at the Montrose site. Either spatial displacement or intraguild predation could potentially restrict habitat use by *A. trinitatis* in sympatry with *A. sagrei*. Although we cannot yet evaluate the consequences of the presence of *A. sagrei* on St. Vincent, the situation should be monitored carefully to determine if long-term effects remain geographically restricted to altered lowlands and to help predict the possible effects of *A. sagrei* invasions on ecologically and structurally similar islands.

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