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World War II-era spotlights testify to the military role of Coconut Island. Today, they remain among decorative plantings utilized extensively by Cuban Brown Anoles (*Anolis sagrei*).

The Anoles of Coconut Island, Kane'ohe Bay, O'ahu, Hawai'i

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Originally, Moku O Lo'e, owned by the Bishop family estate, was used by shepherds and local fishermen. During the 1930s, Christian Holmes, owner of Hawaiian Tuna Packers (now Coral Tuna) and heir to the Fleischmann yeast fortune, purchased the island for his tuna-packing factory. At that time, the island was 12 acres in size and had several coconut trees, which is how it got its popular name, Coconut Island. Holmes, unhappy with the small size of the island, had it expanded to 28 acres and also created many fishponds. Holmes imported hundreds of exotic plants to the island, constructed a large saltwater swimming pool equipped with a slide and a diving board, built outdoor bars at various points around the island, introduced a bowling alley, and reconstructed a shooting gallery that he had bought at an amusement park in San Francisco. Coconut Island even housed a small zoo for a short time. Animal residents included donkeys, a giraffe, monkeys, and a baby elephant. After Holmes's death, these animals became the foundation for the Honolulu Zoo.

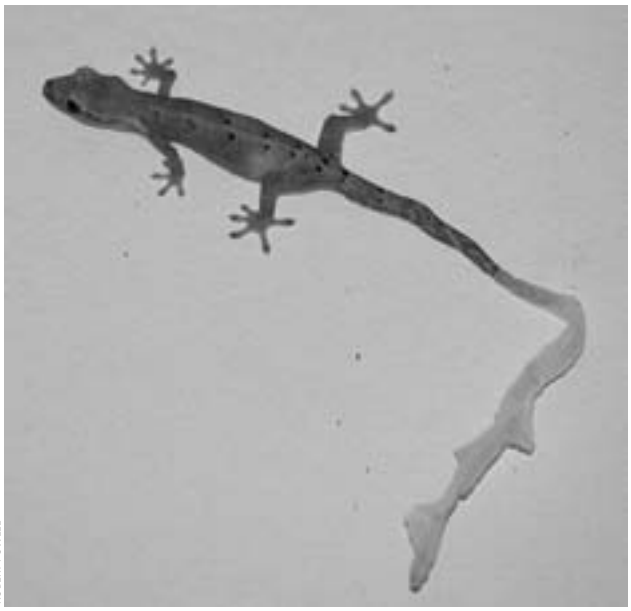
During the war, the military used the island as an R&R post for officers. In 1947, a group of five wealthy oilmen bought

Coconut Island in Kane'ohe Bay. Photograph courtesy of the Hawaii Institute of Marine Biology.

NOLAN ROBERSON

Lagoon on Coconut Island. Plantings in the foreground were occupied by *Anolis sagrei*.

the island. Eventually, one of them, Edwin Pauley, bought out the interests of the other four and became sole owner of the island, where his family spent their summers. Many famous people visited Coconut Island as Pauley's guests. Included among them were Harry Truman, Lyndon B. Johnson, John Wayne, Red Skelton, Richard Nixon, and Ronald Reagan. In 1951, Pauley helped establish the Hawai'i Marine Lab. The name was changed in 1965 to the Hawai'i Institute of Marine Biology, now affiliated with the University of Hawai'i.



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Mourning Geckos (*Lepidodactylus lugubris*), here shedding its skin in one of the suites on Coconut Island, and Stump-toed Geckos (*Gehyra mutilata*) are abundant.

Amphibians and Reptiles of Coconut Island

No terrestrial amphibians or reptiles are native to Hawai'i, but many species have become established, introduced primarily as escaped or released pets. Due to frequent movement of people and materials back-and-forth from O'ahu to Coconut Island, many of the species established in the Kane'ohe area now occur on Coconut Island as well. In 2001, documented species included the Cane Toad (*Bufo marinus*), Stump-toed Gecko (*Gehyra mutilata*), Mourning Gecko (*Lepidodactylus lugubris*), Metallic Skink (*Lampropholis delicata*), and Island Blind Snake (*Ramphotyphlops braminus*). In 2004, two species of *Anolis*, *A. carolinensis* and *A. sagrei*, were found on the island. Both had highly restricted distributions, suggesting that both introductions had occurred shortly before their discovery.

Coconut Island Anoles

Anolis carolinensis, the Green Anole, is moderately sized (SVL of Hawaiian animals = 51–76 mm, total length = 125–230 mm). These lizards are native to the southeastern United States. Populations also have become established in Europe (Spain), Japan (Bonin and Ryukyu islands), the West Indies (Grand Bahama Island, Anguilla), and the Pacific (all of the major Hawaiian islands; Guam; Tinian and Saipan in the Northern Mariana Islands; Yap; Koror and Malakal islands in the Republic of Palau (or Belau). An introduction on Sand Island, Midway Atoll, failed. Green anoles were first reported on O'ahu in 1950, when they were initially misidentified as *A. porcatus* (a closely related Cuban species).

Anolis carolinensis is a "trunk-crown ecomorph" (ecomorphologies anatomically and behaviorally influence microhabitat use as a way of reducing interspecific competition). These lizards are abundant in Hawai'i, especially in gardens and resorts, where introduced plants and insect prey provide suitable conditions. Although they will forage on the ground on occasion, Green

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Cane Toads (*Bufo marinus*) are well-established on Coconut Island.

Anoles spend nearly all of their time on elevated perches in bushes, trees, or artificial substrates like fences and buildings.

Anolis (*Norops*) *sagrei*, the Cuban Brown Anole, is a moderately sized (SVL of Hawaiian animals = 38–64 mm, total length = 130–210 mm) lizard native to Cuba, Bahamas, and Cayman Islands, but which has become established in various mainland (e.g., southeastern United States, Belize, and southern México to northern Honduras) and insular (e.g., St. Vincent, Grenada, Jamaica, Hawai'i [O'ahu and K'auai], and Taiwan) locales. Brown Anoles were first reported on O'ahu in the late 1970s and early 1980s.

Anolis sagrei is a "trunk ground ecomorph," meaning that it spends most of its time within two meters of the ground, and is generally less arboreal than *A. carolinensis*. *Anolis sagrei* is most commonly found in shrubs, on tree trunks, the ground, and rock piles, but readily exploits human dwellings, planters, and fences. It feeds on small invertebrates (mostly insects), but will occasionally take small lizards. Foraging strategies typically exploit an ambush mode, often involving a rapid descent from a vertical, head-down, sit-and-wait posture. This species can also be found in a vertical, heads-up position while basking, especially in the morning.

Both species are habitat generalists, a trait that appears to have served them well as colonists of areas far from their native ranges. Like most anoles, both are diurnal, largely arboreal, primarily insectivorous, and intensely territorial. Several females and juveniles may occupy the territory of a single male. Adult

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Male *Anolis carolinensis* from Coconut Island (2004).

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Female *Anolis carolinensis* from O'ahu (2006). Although apparently extirpated on Coconut Island, Green Anoles remain abundant elsewhere in the Hawaiian Islands.

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Male *Anolis sagrei* from Coconut Island (2006).

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Female *Anolis sagrei* from Coconut Island (2006).

males frequently exploit different microhabitats, such as higher perches, than females or juveniles.

Somewhat more robust than the more gracile Green Anole and apparently more aggressive, introduced *A. sagrei* has largely displaced the native Green Anole, especially in disturbed habitats, where the two species are sympatric in peninsular Florida and elsewhere in the southeastern United States.

Methods

During a visit to Coconut Island in March 2006, we sought to establish the ranges of both species, which we expected to have increased since the discovery of the two populations in 2004. We also examined microhabitat use by anoles in different size classes to test a null hypothesis that perches of lizards of different sizes do not vary.

At various times of day and under varying weather conditions (which were often rainy during our stay), we searched microhabitats where anoles were most likely to be found, concentrating on areas near where they were first observed in 2004. For each anole sighted, we recorded time, size class, height above ground, perch diameter (if applicable), orientation, and various behaviors. Anoles were categorized into three classes: "1" for adult males, "2" for subadult males and adult females (which are sometimes difficult to distinguish from a distance), and "3" for juveniles of indeterminate sex. Orientation on a perch was numerically interpreted as 1 = vertical, facing up; 2 = horizontal; 3 = vertical, facing down. We used StatView 5.0 (SAS Institute, Inc., Cary, North Carolina) for statistical analyses. Means are presented ± 1 standard error.

Results

We were unable to find *Anolis carolinensis*. Shrubs and intermingled vines in the area where they were most abundant in 2004 had been cleared, although considerable, apparently suitable habitat remained, including large Ficus trees where individuals had been observed two years previously.

Anolis sagrei remained abundant in the area where first seen in 2004, and these lizards had expanded their range to nearby areas and to a peninsula characterized by only marginal habitat. Considerably more apparently suitable habitat exists throughout much of the island, including sites adjacent to those where we found lizards. We found no Brown Anoles in the area that had been occupied by *A. carolinensis* in 2004.

For obvious reasons, our investigation of microhabitat use was restricted to *A. sagrei*. We made 82 observations (12 adult males, 50 subadult males/adult females, 18 juveniles, and 2 for which size class was not recorded). Most (n = 65) were under cloudy skies or during rain. Seven observations were of individuals on the ground, 18 on rocks, 17 on artificial perches (e.g., pipe, box, debris, planter), 8 on stumps or logs, and 32 on vegetation. Of the latter, 20 were on leaves. We observed one individual eating (small arthropod), one mating pair, one other incidence of courting behavior, and two territorial displays. Fifteen instances of elicited escape behavior included 10 individuals jumping to the ground or crawling under an object on the ground and five lizards jumping onto vegetation, four of them from rocks or the ground.

Distribution of *Anolis sagrei* in 2004 (narrow dashed line) and in 2006 (solid narrow line) and of *A. carolinensis* in 2004 (broad solid line).

Mean perch height for all size classes was 35.1 ± 2.8 cm (n = 79), mean perch diameter was 8.7 ± 1.9 cm, and mean orientation was 1.9 ± 0.1, or predominantly horizontal.

Perch heights of adult males (53.8 ± 6.6 cm, n = 12) were significantly higher than those of subadult males and adult females (34.1 ± 3.5 cm, n = 48) and those of juveniles (29.1 ± 5.1 cm, n = 17; ANOVA, P = 0.02). Mean perch height differences between classes 1 and 2 (19.7 cm) and between classes 1 and 3 (24.6 cm) were significant (Fisher's PLSD, both P = 0.01). However, mean perch height differences between classes 2 and 3 (5.0 cm) were not significant (P = 0.45).

Perch diameters used by anoles in different size classes did not differ significantly (ANOVA, P = 0.82), nor were any differences between any two classes significant (Fisher's PLSD, between classes 1 and 2 P = 0.65, between classes 1 and 3 P = 0.54, between classes 2 and 3 P = 0.69). Similarly, orientations did not differ significantly among classes (ANOVA, P = 0.97), nor between individual classes (Fisher's PLSD; not valid between classes 1 and 2 due to limited sample sizes; between classes 1 and 3, P = 0.85; between classes 2 and 3, P = 0.80).

Discussion

The apparent absence of *Anolis carolinensis* may represent one of the few documented failed colonization attempts by any invasive reptile. Despite the altered vegetation in the area where these lizards were most commonly encountered in 2004, the presence of apparently suitable habitat, including some used by Green Anoles in 2004, suggests that other factors are involved. Because we found no *A. sagrei* anywhere near where *A. carolinensis* had been found previously, we have ruled out displacement as a consequence of interspecific competition. In a concurrent survey of

ROBERT POWELL

An adult male Cuban Brown Anole (*Anolis sagrei*) seeks shelter in vegetation near the base of a large Banyan Tree (*Ficus benghalensis*) on Coconut Island in 2006. Ecologically versatile, these anoles readily exploit large trees, small bushes and shrubs, as well as walls, buildings, and human debris.

birds, we did find many more introduced Red-Vented Bulbuls (*Pycnonotus cafer*) and a lesser number of Red-whiskered Bulbuls (*P. jocosus*) than had been observed during similar surveys in 2001 and 2004. Both species are known predators of diurnal lizards, both in their native range (Indian Subcontinent through southeastern Asia) and in Hawai'i. The combination of altered vegetation and presumably increased predation pressures may have combined to eliminate Green Anoles from Coconut Island.

Although *Anolis sagrei* remains present and has expanded its range on the island, the extent of the expanded range in light of abundantly available and apparently suitable habitat is much less than we had expected. Because vegetation in the areas occupied by Brown Anoles had not been substantively altered, bulbuls may be implicated in the slower-than-expected exploitation of suitable habitats by *A. sagrei*.

Activity may have been suppressed by inclement weather, but observed perch choices and escape behaviors were compatible with expectations for a trunk-ground anole. Males selecting higher perches and the sexual size dimorphism evident in these lizards may serve to spatially partition resources among different size classes, thereby reducing intraspecific competition. Larger animals (i.e., adult males) perching higher than smaller conspecifics may indicate that the former are able to take advantage of their size to monopolize microhabitats that facilitate optimal foraging. These more elevated positions also may result in more distinct territorial boundaries between conspecific males.

SCOTT STREIT (WWW.BIRD-FRIENDS.COM)

Red-vented Bulbuls (*Pycnonotus cafer*) are aggressive predators on small, diurnal lizards. These introduced birds have become increasingly common on Coconut Island.

Data regarding perch diameters were equivocal due to too few observations of adult males and juveniles (n = 1 in each instance). This does reflect the large number of observations of animals using perches other than those for which diameter data were appropriate (e.g., the ground, rocks, and artifical perches such as boxes, refuse, and even buildings). This conforms to observations for this species in other areas, and to expectations for a trunk-ground ecomorph. The same frequency of occurrence on the ground and common use of rocks and artificial perches were undoubtedly responsible for the fact that most anoles were oriented horizontally, which did not vary among size classes.

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References

Birding Hawaii. 2003. Non-Avian Wildlife of Hawai'i – On the Ground. Birding Hawaii (www.birdinghawaii.co.uk/nonavianground2.htm).

Campbell, T. 2001. Invader of the Month: The Brown Anole, *Anolis sagrei.* Institute for Biological Invasions (invasions.bio.utk.edu/invaders/sagrei.html).

Campbell, T. and A. Echternacht. 2003. Introduced species as moving targets: Changes in body sizes of introduced lizards following experimental introductions and historical invasions. *Biological Invasions* 5: 193–212.

Casanova, L. 2004. *Norops sagrei*, Animal Diversity Web (animaldiversity.ummz.umich.edu/site/accounts/information/Norops_sagrei.html).

Decker, H., R. Powell, and A.M. Bauer. 2003. Gecko populations on Coconut Island, Hawai'i. *Gekkota* 4: 25–33.

Fernandez, E., T. Prince, S. Salas-Vega, M. Tablante, J. Lee, V. Manteuffel, K. Trotta. 2001. The Effects of Age and Gender on Aggressive Responses of Adult Male Brown Anoles (*Anolis sagrei*). University of Miami Department of Biology (www.bio.miami.edu/ecosummer/eco2001/wizardpaper.html).

Gerber, G. and A. Echternacht. 2000. Evidence for asymmetrical intraguild predation between native and introduced *Anolis* lizards. *Oecologia* 124: 599–607.

Gorgoy, L. 2000. *Anolis sagrei* Dumeril and Bibron, 1837. Caribbean Anole Database (www.anole.net/sagrei.html).

Hawaii Audubon Society. 2005. *Hawaii's Birds.* 6th ed. Hawaii Audubon Society, Honolulu.

HIMB (Hawai'I Institute of Marine Biology). 2005. A Brief History of Moku O Lo'e — "Coconut Island" (www.hawaii.edu/HIMB/history.html).

Invasive Species Specialist Group. 2006. *Norops sagrei.* Global Invasive Species Database (www.invasivespecies.net/database/species/ecology.asp?si= 603 &fr=1&sts=).

Lever, C. 2003. *Naturalized Reptiles and Amphibians of the World.* Oxford University Press, New York.

McKeown, S. 1996. *A Field Guide to Reptiles and Amphibians in the Hawaiian Islands.* Diamond Head Publ., Inc., Los Osos, California.

Pansza, J.M. and R. Powell. 2005. Geographic distribution: *Anolis carolinensis. Herpetological Review* 36: 201.

Powell, R. 1992. *Anolis porcatus. Catalogue of American Amphibians and Reptiles* (541): 1–5.

Powell, R. 2001. Amphibians and Reptiles (of Coconut Island) (www.avila.edu/hawaii/AmpRep_CoconutIslans.htm).

Powell, R. and J.M. Pansza. 2005. Geographic distribution: *Anolis sagrei. Herpetological Review* 36: 201.