



INTRODUCED SPECIES

First Specimen of an American Green Anole (*Anolis carolinensis*) on the Oceanic Island of Bermuda, with a Review of the Species' Current Global Distribution

 James T. Stroud^{1,2}, Mark Outerbridge³, and Sean T. Giery⁴
¹Department of Biological Sciences, Florida International University, 11200 SW 8th St., Miami, Florida 33199 (jameststroud@gmail.com)

²Fairchild Tropical Botanical Gardens, Coral Gables, Florida 33156

³Wildlife Ecologist, Department of Environment and Natural Resources, Bermuda Government (mouterbridge@gov.bm)

⁴Department of Biological Sciences, North Carolina State University, Raleigh, North Carolina 27695-7617 (stgiery@gmail.com)

The isolated islands of Bermuda, located ca. 1,000 km east of North Carolina, USA in the Atlantic Ocean, have a rich history of non-native species introductions (see Sterrer et al. 2004). Although Bermuda supports only one endemic lizard, the Bermuda Skink (*Plestiodon* [*Eumeces*] *longirostris*), four species of non-native anoles have been introduced and become established over the past century (Losos 1996; Stroud et al. 2016). In the early 20th Century, Jamaican Anoles (*Anolis grahami*) were introduced as (ultimately unsuccessful) biological control agents of crop-destroying insects (Wingate 1965). In the 1940s, two additional non-native anoles became established. The discovery of the Antiguan Giant Anole (*A. leachii*), referred to locally as the “Warwick Lizard,” at the Bermuda Botanical Gardens in central Bermuda, was followed by the discovery of the Barbadian Anole (*A. extremus*) in extreme northwestern Bermuda (Wingate 1965; Losos 1996). Most recently, Cuban Brown Anoles (*A. sagrei*) have been recorded from two geographically independent locations in Bermuda, after having first been observed in 2013 (Stroud et al. 2016).

Here we present the first confirmed record of a single individual of a fifth species on Bermuda, likely to be the American Green Anole (*Anolis carolinensis* Voigt 1832). An earlier record of a single *A. carolinensis* specimen captured on Bermuda in 1876 (then labeled “*A. principalis*,” which has since been synonymized with *A. carolinensis*; Verrill 1902) lacks a detailed account of the event and no specimen is available for assessment.

On 26 March 2016, a single adult male *A. carolinensis* (Fig. 1) was caught by a member of the public at a cargo dock in Hamilton, Bermuda (32.292, -64.779; Fig. 2) and brought to the Bermuda Aquarium, Museum and Zoo (BAMZ). The Hamilton cargo dockyard is a heavily urbanized environment

with sparse trees (Fig. 3). Despite being phenotypically similar to two other established species on Bermuda (the Jamaican Anole, *A. grahami*, and the Barbadian Anole, *A. extremus*), a member of the public recognized it as different and thought it warranted capture. The captured lizard measured 65 mm SVL (173 mm total length) and weighed 6.3 g. The lizard was euthanized and accessioned into the Bermuda Natural History Museum collection (Specimen No. 2016 296 009). Representatives from the Department of Environment and Natural Resources failed to find any other individuals during



Fig 1. An adult male American Green Anole (*Anolis carolinensis*) intercepted at Hamilton cargo dock, Bermuda. Photographs by Mark Outerbridge.

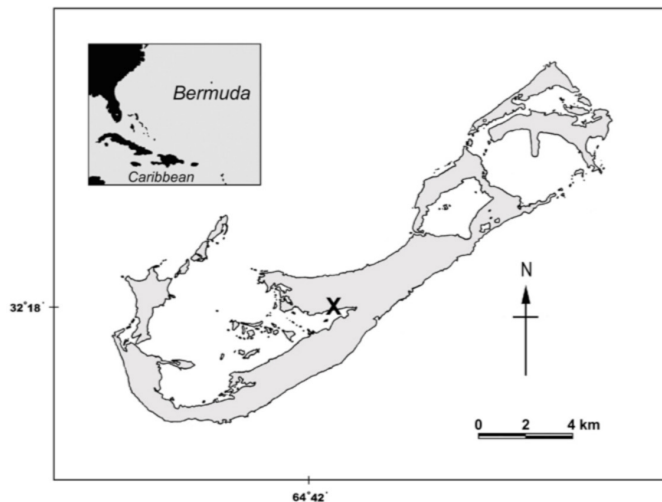


Fig 2. Collection location (black cross) of single adult male American Green Anole (*Anolis carolinensis*) intercepted at the Hamilton cargo dock in Bermuda.

intensive searches. Given the location of capture, this individual probably arrived in Bermuda as a stowaway on a cargo ship.

In the absence of molecular analysis, this lizard might be a Cuban Green Anole (*A. porcatius*), as phenotypic distinction of *A. porcatius* and *A. carolinensis* is extremely difficult (Camposano 2011). Hybridization between these sister species also is possible (Kolbe et al. 2007). Given the wide global distribution of *A. carolinensis* and the higher likelihood of trade cargo arriving to Bermuda from the USA than Cuba (Helmus et al. 2014), we conservatively attribute this specimen to *A. carolinensis*.

Global Distribution of *Anolis carolinensis*

The American Green Anole (*A. carolinensis*) is native throughout the southeastern USA (Fig. 4), following initial colonization of southern Florida from Cuba by an ancestral species (Glor et al. 2005). Within its native range, *A. carolinensis* comprises five strongly supported phylogeographic groups



Fig 3. Hamilton cargo docks, Bermuda. The location of the captured adult male American Green Anole (*Anolis carolinensis*). Photographs by Mark Outerbridge.

(South Florida, East Florida, North-West Florida, Gulf-Atlantic region, and the Carolinas; Manthey et al. 2016).

Outside of its native range, *Anolis carolinensis* is globally widespread (Kraus 2008), although many of these records do not constitute established populations (see Fig. 4). At present, non-native records within the mainland USA include San Diego (Jones and Lovich 2009) and Los Angeles, California (Pauly 2013), Kansas, Maryland, western Texas, and West Virginia (Kraus 2008 and references therein). Outside of the mainland USA, *A. carolinensis* has been recorded throughout the Caribbean, in Anguilla, Grand Bahama, and the Cayman Islands, and at some sites on mainland Central America, including Belize and Mexico (Kraus 2008 and references therein).

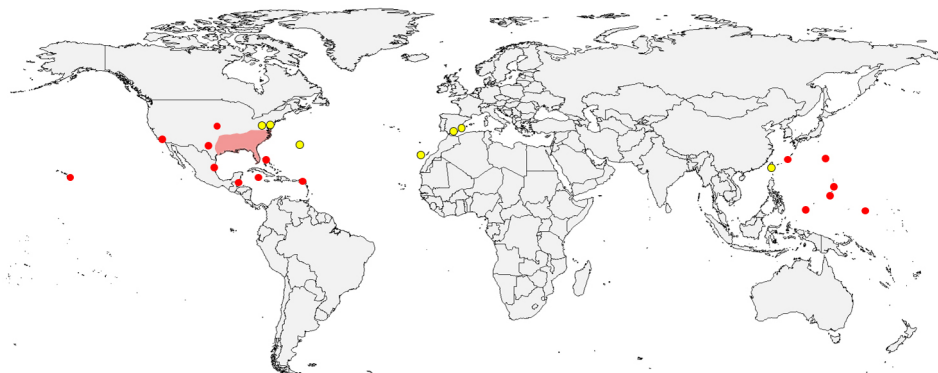


Fig 4. The native (red shade) and non-native (established: red dots, not established: yellow dots) global distribution of American Green Anoles (*Anolis carolinensis*).

East Asian and South Pacific records include Taiwan (Norval et al. 2012), as well as the Japanese Ryukyu and Ogasawara island chains, and the Pacific islands of Hawaii, Guam, Northern Mariana Islands, Palau, and Micronesia (Kraus 2008 and references therein).

None of the European records on mainland Spain and the Canary Islands (Pleguezuelos et al. 2002; Pleguezuelos 2004) have led to established populations. Given the continued wide availability of *A. carolinensis* in the global pet trade, new non-native records and populations from either intentional or incidental release are likely to be discovered.

Acknowledgements

We thank the staff at Stevedoring Services Ltd. (Bermuda) for capturing the lizard and delivering it to the Bermuda Aquarium, Museum and Zoo. This is Contribution #249, Bermuda Biodiversity Project (BBP), Bermuda Aquarium, Natural History Museum and Zoo, Department of Environment and Natural Resources.

Literature Cited

- Camposano, B.J. 2011. Morphological Species Verification and Geographic Distribution of *Anolis* (Sauria: Polychrotidae) in Florida. Unpublished M.S. Thesis, University of Florida, Gainesville.
- Glor, R.E., Losos, J.B. and A. Larson. 2005. Out of Cuba: Overwater dispersal and speciation among lizards in the *Anolis carolinensis* subgroup. *Molecular Ecology* 14: 2419–2432.
- Helmus, M.R., D.L. Mahler, and J.B. Losos. 2014. Island biogeography in the Anthropocene. *Nature* 513: 543–546.
- Jones, L.L.C. and R.E. Lovich. 2009. *Lizards of the American Southwest: A photographic field guide*. Rio Nuevo Publishers.
- Kolbe, J.J., R.E. Glor, L. Rodríguez-Schettino, A. Chamizo-Lara, A. Larson, and J.B. Losos. 2007. Multiple sources, admixture, and genetic variation in introduced *Anolis* lizard populations. *Conservation Biology* 21: 1612–1625.
- Kraus, F. 2008. *Alien Reptiles and Amphibians: A Scientific Compendium and Analysis*. Springer, Dordrecht, The Netherlands.
- Manthey, J.D., M. Tollis, A.R. Lennon, E.M. Lemmon, and S. Boissinot. 2016. Diversification in wild populations of the model organism *Anolis carolinensis*: A genome-wide phylogeographic investigation. *Ecology and Evolution*: DOI: 10.1002/ece3.2547.
- Losos, J.B. 1996. Dynamics of range expansion by three introduced species of *Anolis* lizards on Bermuda. *Journal of Herpetology* 30: 204–210.
- Norval, G., J.-J. Mao, and S.R. Goldberg. 2012. A record of a green anole (*Anolis carolinensis* Voigt 1832), from the wild in southwestern Taiwan. *Herpetology Notes* 5: 95–97.
- Pauly, G. 2013. Green anoles in Hancock Park! Natural History Museum, Los Angeles County, California (<http://www.nhm.org/nature/blog/green-anoles-hancock-park>).
- Pleguezuelos, J.M. 2004. Las especies introducidas de anfibios y reptiles, pp. 502–532. In: J.M. Pleguezuelos, R. Márquez, and M. Lizana (eds.), *Atlas y Libro Rojo de los Anfibios y Reptiles de España*. 3a impresión. Dirección General de la Conservación de la Naturaleza-Asociación Herpetológica Española, Madrid.
- Pleguezuelos, J.M., R. Márquez, and M. Lizana. 2002. *Atlas y Libro Rojo de los Anfibios y Reptiles de España*. Dirección General de la Conservación de la Naturaleza-Asociación Herpetológica Española, Madrid.
- Sterrer, W.E., A.F. Glasspool, H. DeSilva, and J. Furbert. 2004. Bermuda – An Island Biodiversity Transported, pp. 118–170. In: J. Davenport and J.L. Davenport (eds.), *The Effects of Human Transport on Ecosystems: Cars and Planes, Boats and Trains*. Royal Irish Academy, Dublin.
- Stroud, J.T., S.T. Giery, and M. Outerbridge 2016. Establishment of *Anolis sagrei* on Bermuda represents a novel ecological threat to Critically Endangered Bermuda Skinks (*Plestiodon longirostris*). *Biological Invasions*: in press.
- Wingate, D.B., 1965. Terrestrial herpetofauna of Bermuda. *Herpetologica* 21: 202–218.