Herpetology Notes, volume 11: 761-764 (2018) (published online on 06 September 2018)

A second Caribbean anole lizard species introduced to Brazil

Jane C. F. Oliveira[1,*], Thiago Marcial de Castro[2], Davor Vrcibradic[3], Matheus Campos Drago[3], and Ivan Prates[4]

Biological invasions are one of the main threats to biodiversity (Mack et al., 2000). Introduced organisms may negatively affect native species and ecosystems, for instance by imposing new competition and predation pressures and introducing new pathogens (e.g. Blackburn et al., 2014; Miaud et al., 2016). Because exotic species are usually difficult to control once they become invasive (Genovesi, 2005), it is important to promptly detect and document new introductions.

All over the world, an increasing number of introductions by exotic lizard species have been documented, with successful establishment often leading to major ecological impacts (e.g. Krysko et al., 2004; Engeman et al., 2011; Vasconcelos et al., 2014; Kraus, 2015). This is the case for a number of anole species (*Anolis*, Dactyloidae), which have been widely reported outside their natural ranges, following human-mediated introductions (e.g. Eales et al., 2008; Nicholson and Richards, 2011; Samelo and Barrela, 2016; Yasumiba et al., 2016). Among them, the brown or festive anole, *Anolis sagrei* Duméril and Bibron, 1837, has arguably become one of the most widespread exotic reptiles worldwide. Native to Cuba, the Bahamas, and the Cayman islands, *Anolis sagrei* has been detected as an invasive species in several countries in the Americas and Asia (Greene et al., 2002; Norval et al., 2002; Kolbe et al., 2004; Tan and Lim, 2012; Granatosky and Krysko, 2013; Stroud et al., 2017). Following introductions, this species can reach high population densities and undergo rapid range expansion (Kolbe et al., 2004). In South America, the occurrence of *A. sagrei* was recently reported for the first time based on specimens found in coastal Ecuador, where it was likely introduced through human-mediated transportation,

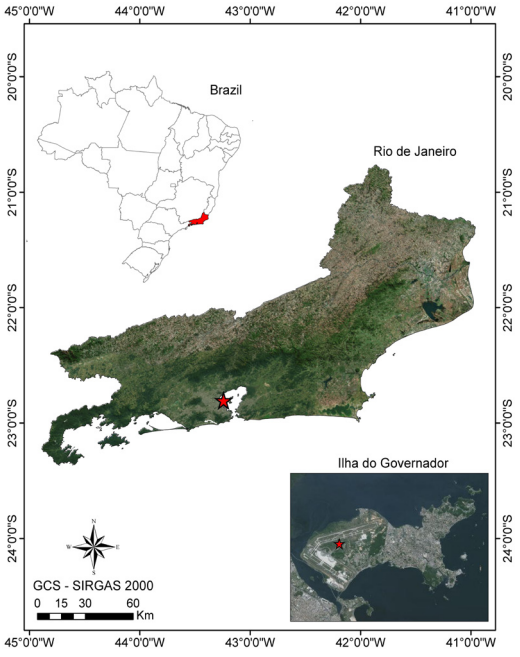

Figure 1. Location of the site (red star) where specimens of *Anolis sagrei* were sampled at the Antonio Carlos Jobim (Galeão) International Airport, in the metropolitan area of Rio de Janeiro city, southeastern Brazil.

[1] Departamento de Ecologia, Instituto de Biologia Roberto de Alcantara Gomes, Universidade do Estado do Rio de Janeiro, Rua São Francisco Xavier 524, Maracanã, 20550-019, Rio de Janeiro, Rio de Janeiro, Brazil.

[2] Centro Universitário São Camilo, Rua São Camilo de Lellis, 1, Paraíso, Cachoeiro de Itapemirim, 29304-910, Espírito Santo, Brazil.

[3] Instituto de Biociências, Universidade Federal do Estado do Rio de Janeiro, Avenida Pasteur 458, Urca, 22290-240, Rio de Janeiro, Brazil.

[4] Department of Vertebrate Zoology, National Museum of Natural History, Smithsonian Institution, Washington, DC 20560-0162, USA.

[*] Corresponding author. E-mail: janeherpeto@gmail.com

Figure 2. Adult males of *Anolis sagrei* collected at the Galeão International Airport, in Rio de Janeiro city, Brazil. A) detail of the dewlap of a specimen (MNRJ 26779); B) uniform colour pattern of another specimen (MNRJ 26784). Photos by J. C. F. Oliveira.

such as aboard commercial ships (Amador et al., 2017). In this contribution, we provide the first record of this aggressive invasive lizard in Brazil.

We recorded specimens of *Anolis sagrei* during fieldwork carried out within the limits of the Antonio Carlos Jobim International Airport, aka Galeão Airport (-22.8052, -43.2413, WGS84; 6 m elevation), in the metropolitan area of the city of Rio de Janeiro, southeastern Brazil (Figure 1). The surveyed area is characterized by highly fragmented and anthropically altered lowland Atlantic Rainforest vegetation. Surveys were carried out in 10 January 2017 (summer, the rainy season) and 13 June 2017 (winter, the drier and cooler season), during the morning. Lizards were collected manually or using elastic rubber bands and sacrificed with an intraperitoneal injection of veterinary anesthetic (lidocaine). Collecting permits were issued by Brazil's ICMBio (SISBIO/56517-1) and the Galeão Airport. Specimens were deposited in the Museu Nacional – Universidade Federal do Rio de Janeiro, in Rio de Janeiro, Brazil (voucher numbers MNRJ 26779-84).

Species identification was based on scale characters and colour pattern and on the diagnoses provided by Savage (2002) and Amador et al. (2017), and confirmed by expert opinion (Dr. Miguel T. Rodrigues, Universidade de São Paulo, Brazil; Dr. Kevin de Queiroz, Smithsonian Institution, USA) based on photographs of live specimens.

We collected six individuals of *A. sagrei* during fieldwork (one in January and five in June). Colour pattern of these specimens varied from dark brown with lighter markings to uniform light brown or beige (Figure 2A), often in the same individual at different moments. These specimens are morphologically consistent with those of other populations of *Anolis sagrei* from both native and introduced ranges based on morphometrics and pholidosis (Table 1). This species is promptly recognized in the field by having a well-developed dewlap with a red or orange background and a yellow rim, as well as two dark bars above the eyes (Figure 2A,B; Savage, 2002; Amador et al., 2017). These traits distinguish *A. sagrei* from the five native Atlantic Forest anole species, namely *Anolis fuscoauratus*, *A. nasofrontalis*, *A. ortonii*, *A. pseudotigrinus*, and *A. punctatus* (Prates et al., 2017). Of these, *A. fuscoauratus* and *A. ortonii* are the most similar to *A. sagrei* due to their similar body size, brownish/greyish dorsal coloration and reddish dewlap (variable in *A. fuscoauratus*), but our specimens differ from both species (and agree with *A. sagrei*) in having keeled ventrals (vs. smooth), 5-6 supralabials (vs. 7-10) and a laterally compressed tail (vs. round in cross section) (see Avila-Pires, 1995).

We found males and females of *Anolis sagrei* perched on vegetation and on the ground, next to a construction site. These animals perched at heights up to 1.5 m on herbaceous plants, and up to 3.0 m on small trees, which is considered typical for the species (Losos et al., 1993). During sampling trips, we observed males of *Anolis sagrei* extending their dewlaps, apparently performing territorial displays. We also observed juveniles (in both months; not collected) and one pair of adults copulating (in January; the male was collected). At the study site,

Table 1. Morphometric characters of *Anolis sagrei* from Rio de Janeiro, Brazil, compared to those of five other populations from its native (Cuba) and introduced range (the remaining four) based on data from Amador et al. (2017).

Locality	Brazil (Rio de Janeiro)	Mexico (Yucatan)	Cuba (Cardeñao and Kabama)		Honduras (San Pedro Sula)		Taiwan (Chiayi)		Ecuador (Guayaquil)	
Sex	Male	Male	Male	Female	Male	Female	Male	Female	Male	Female
Sample	6	1	4	1	1	1	15	16	2	3
Supralabials	5-6	5-6	4-6	5	4-5	4-5	5-6	4-6	5	5
Internasal scales	5-6	7	5-7	6	6	6	5-6	4-6	6-7	6-7
Lamellae 4th toe	31-34	33	29-33	31	32	30	29-35	28-34	35-37	35-37
Head lengh	10.7-16.1	12.7	11.2-16.2	10.7	15.7	12.7	13-17	10.0-11.9	11.1-15.5	11.8-12.6
Tibia lengh	10.3-14.2	10.2	9.5-16.7	9.2	15.5	12.1	11.6-14.9	7.7-10.5	8.6-14.4	9.4-9.9
SVL	35.9-59.0	41.2	38.8-62.7	38.2	59.4	48.1	47.0-62.1	34.9-44.0	38.6-54.2	42.3-43.4

we observed two other lizards co-occurring with *A. sagrei*, namely *Tropidurus torquatus* (Tropiduridae) and *Cnemidophorus* gr. *lemniscatus* (Teiidae).

This study provides the first record of *Anolis sagrei* as an introduced species in Brazil. This is also the second record of the brown anole in South America, following its recent detection in Guayaquil, Ecuador (on South America's Pacific coast), some 4,600 km northwest of Rio de Janeiro (Amador et al., 2017). To our knowledge, the presence of *A. sagrei* in southeast Brazil (on South America's Atlantic coast) represents the most meridional record of this species to date.

The observation of juveniles and mating couples in the Galeão Airport suggests that *Anolis sagrei* is established locally, which represents the second case of an established exotic anole species in Brazil. The first case was that of *Anolis porcatus* (also native to Cuba), which was recently reported from the Baixada Santista, state of São Paulo (around 340 km southwest of Rio de Janeiro), in coastal southeastern Brazil, possibly as a result of overseas transportation by ships (Prates et al., 2016; Samelo and Barrela, 2016). Before that, a single individual assigned to *Anolis carolinensis* was found in the state of Bahia in northeastern Brazil, though with no evidence of an established population (Fonseca et al., 2014), which might nonetheless reflect lack of subsequent sampling. While the source of introduction of *A. sagrei* in Brazil is currently unknown, its occurrence within the premises of an international airport is consistent with a scenario of unintentional transportation by airplanes, presumably within or amongst air cargo.

The actual geographic extent and potential for spread of *Anolis sagrei* in Rio de Janeiro and in Brazil are currently unclear. This species may be presently restricted to the Galeão Airport area, or to the continental island where this airport is located (Ilha do Governador). This island is nonetheless separated from the mainland by a narrow canal (~300 m), and connected to the continent by multiple bridges. In the event of range expansions, it remains to be seen whether *A. sagrei* will be able to colonize natural environments, such as the surrounding Atlantic Rainforest remnants. These lizards thrive in human-modified settings and altered habitats such as forest edges, yet do not seem to reach high densities in closed-canopy forests (Huang et al., 2008a).

The establishment of brown anole populations elsewhere has led to shifts in substrate use by native anoles (Losos et al., 1993; Stuart et al., 2014), as well as promoted major shifts in the structure of local insect assemblages (Huang et al., 2008b). As such, this species has the potential of affecting local ecological communities in Brazil. However, the effects of the establishment of *A. sagrei* on the local lizard species found coexisting with it at our study site are difficult to predict. *Tropidurus torquatus* is a semi-scansorial sit-and-wait forager like *A. sagrei*, but reaches a much larger adult size (ca. 100 mm SVL), whereas *Cnemidophorus* gr. *lemniscatus* is a terrestrial lizard that forages widely (and, thus, very distinct ecologically from *A. sagrei*). Further inventories are necessary to shed light on whether and to what extent *Anolis sagrei* may be able to extend its range in Brazil, as well as its potential to affect the native ecological communities, particularly in Atlantic Rainforest areas.

Acknowledgments. We thank the administration of the Antonio Carlos Jobim International Airport for providing access to the study site. Species identification was kindly confirmed by Dr. Miguel T. Rodrigues and Dr. Kevin de Queiroz. Danielle Rivera provided comments that helped to improve this manuscript. JCFO thanks Programa de Pós Doutorado FAPERJ Nota 10

(Process n° E-26/202.388/2017). IP acknowledges funding from a Smithsonian Peter Buck Postdoctoral Fellowship.

References

Amador, L., Ayala-Varela, F., Nárvaez. A.E., Cruz, K. Torres-Carvajal, O. (2017): First record of the invasive Brown Anole, *Anolis sagrei* Duméril & Bibron, 1837 (Squamata: Iguanidae: Dactyloinae), in South America. Check List **13**(2): 2083.

Ávila-Pires, T.C.S. (1995): Lizards of Brazilian Amazonia. Zoologische Verhandelingen **299**: 1–706.

Blackburn, T.M., Essl, F., Evans, T., Hulme, P.E., Jeschke, J.M., Kühn, I., Kumschick, S., Marková, Z., Mrugała, A., Nentwig, W., Pergl, J. (2014): A unified classification of alien species based on the magnitude of their environmental impacts. Plos Biology **12**(5): e1001850.

Eales, J., Thorpe, R.S., Malhotra, A. (2008): Weak founder effect signal in a recent introduction of Caribbean *Anolis*. Molecular Ecology **17**(6): 1416–1426.

Engeman, R., Jacobson, E., Avery, M.L., Meshaka, W.E. (2011): The aggressive invasion of exotic reptiles in Florida with a focus on prominent species: A review. Current Zoology **57**(5): 599–612.

Fonseca E., Marques, R., Tinoco, M.S. (2014): Geographic Distribution: *Anolis carolinensis* (Green Anole). Herpetological Review **45**(4): 658.

Genovesi, P. (2005): Eradications of invasive alien species in Europe: a review. Biological Invasions **7**(1): 127–133.

Granatosky, M.C., Krysko, K.L. (2013): The Brown Anole, *Anolis sagrei* Duméril and Bibron 1837 (Dactyloidae), state record and introduction pathway. IRCF Reptiles & Amphibians **20**(4): 190–191.

Greene, B.T., Yorks, D.T., Parmerlee Jr, J.S., Powell R, Henderson RW. (2002): Discovery of *Anolis sagrei* in Grenada with comments on its potential impact on native anoles. Caribbean Journal of Science **38**(3–4): 270–272.

Huang, S.C., Norval, G., Wei, C.S., Tso, I.M. (2008a): Effects of the brown anole invasion and betelnut palm planting on arthropod diversity in southern Taiwan. Zoological Science **25**(11): 1121–1129.

Huang, S.C., Norval, G., Tso, I.M. (2008b): Predation by an exotic lizard, *Anolis sagrei*, alters the ant community structure in betelnut palm plantations in southern Taiwan. Ecological Entomology **33**(5): 569–576.

Kolbe, J.J., Glor, R.E., Schettino, L.R., Lara, A.C., Larson, A., Losos, J.B. (2004): Genetic variation increases during biological invasion by a Cuban lizard. Nature **431**: 177–181.

Kraus, F. (2015): Impacts from invasive reptiles and amphibians. Annual Review of Ecology, Evolution, and Systematics **46**:75–97.

Krysko, K.L., Enge, K.M., King, F.W. (2004): The veiled chameleon, *Chamaeleo calyptratus* Duméril and Bibron 1851 (Sauria: Chamaeleonidae): a new exotic species in Florida. Florida Scientist **67**(4):249–253.

Losos, J.B., Markes, J.C., Schoener, T.W. (1993): Habitat use and Ecological interactions of an introduced and a native species of *Anolis* lizard on Grand Cayman, with a review of the outcomes of anole introductions. Oecologia **95**(4): 525–532.

Mack RN, Simberloff, D., Lonsdale, W.M., Evans, H., Clout, M., Bazzaz, F.A. (2000): Biotic invasions: causes, epidemiology, global consequences, and control. Ecological Applications **10**(3):689–710.

Miaud, C., Dejean, T., Savard, K., Millery-Vigues, A., Valentini, A., Gaudin, N.C.G., Garner, T.W.J. (2016): Invasive North American bullfrogs transmit lethal fungus *Batrachochytrium dendrobatidis* infections to native amphibian host species. Biological Invasions **18**(8): 2299–2308.

Nicholson, K.E., Richards, P.M. (2011): Home-range size and overlap within an introduced population of the Cuban Knight Anole, *Anolis equestris* (Squamata: Iguanidae). Phyllomedusa **10**(1): 65–73.

Norval, G., Mao, J.J., Chu, H.P., Chen, L. C. (2002): A new record of an introduced species, the Brown Anole (*Anolis sagrei*) (Duméril & Bibron, 1837), in Taiwan. Zoological Studies **41**(3): 332–336.

Oliveira, J.C.F., Ribeiro, J.P., Winck, G.R., Rocha, C.F.D., Pralon, E., Silva, M.B., Avila-Pires, T.C.S. (2015): *Cnemidophorus cryptus*. Geographic distribution. Herpetological Review **46**(1): 58–59.

Prates, I., Hernandez, L., Samelo, R.R.,Carnaval, A.C. (2016): Molecular identification and geographic origin of an exotic anole lizard introduced to Brazil, with remarks on its natural history. South American Journal of Herpetology **11**(3): 220–227.

Prates, I., Melo-Sampaio, P.R., Drummond, L.O., Teixeira Jr, M., Rodrigues, M.T., Carnaval, A.C. (2017): Biogeographic links between southern Atlantic Forest and western South America: rediscovery, redescription, and phylogenetic relationships of two rare montane anole lizards from Brazil. Molecular Phylogenetics and Evolution **113**: 49–58.

Samelo, R.R., Barrella, W. (2016): Geographic distribution: *Anolis porcatus* (Cuban Green Anole). Herpetological Review **47**(2): 256.

Savage, J.M. (2002): The amphibians and reptiles of Costa Rica: a herpetofauna between two continents, between two seas. Chicago Press. 934 p.

Stroud, J.T., Giery, S.T., Outerbridge, M.E. (2017): Establishment of *Anolis sagrei* on Bermuda represents a novel ecological threat to critically endangered Bermuda skinks (*Plestiodon longirostris*). Biological Invasions **19**(6): 1723–1731.

Stuart, Y.E., Campbell, T.S., Hohenlohe, P.A., Reynolds, R.G., Revell, L.J., Losos, J.B. (2014): Rapid evolution of a native species following invasion by a congener. Science **346**(6208): 463–466.

Tan, H.H., Lim, K.K.P. (2012): Recent introduction of the brown anole *Norops sagrei* (Reptilia: Squamata: Dactyloidae) to Singapore. Nature in Singapore **5**: 359–362.

Vasconcelos, R., Martins, B.H., Lopes, E. (2014): *Agama agama*: a charter tourist in the Cape Verde Islands? African Journal of Herpetology **63**(1): 34–46.

Yasumiba, K., Okada, A., Okochi, I., Iwai, N. (2016): Minimum longevity and growth of the invasive green anole, *Anolis carolinensis*, in Chichi-jima of the Ogasawara Islands, Japan. Current Herpetology **35**(2): 101–105.

Accepted by Graham Walters