



## INTRODUCED SPECIES

# The Known Distribution of an Invasive Lizard, the Brown Anole (*Anolis sagrei* Duméril & Bibron, 1837), in Taiwan

Gerrut Norval<sup>1</sup>, Guo-Quan Wang<sup>2</sup>, Jean-Jay Mao<sup>3</sup>, Li-Xhan Liu<sup>3</sup>, Meng-Hsien Chuang<sup>4</sup>, Yi-Ju Yang<sup>5</sup>, Kerry Slater<sup>1</sup>, and Leslie R. Brown<sup>1</sup>

<sup>1</sup>Applied Behavioural Ecology and Ecosystem Research Unit, Department of Environmental Sciences, UNISA, Private Bag X6, Florida, 1710, Republic of South Africa (gnorval@gmail.com)

<sup>2</sup>Department of Life Science, National Cheng Kung University, No.1 University Rd., Tainan City, 701, Taiwan, Republic of China

<sup>3</sup>Department of Forestry and Natural Resources, National Ilan University, No. 1, Sec. 1, Shen-Lung Rd., Yilan, 260, Taiwan, Republic of China

<sup>4</sup>Environmental Education and Ecological Conservation Extension Center, Aletheia University, No. 70-11 Beishiliao, Madou District, Tainan City, 721, Taiwan, Republic of China

<sup>5</sup>Department of Natural Resources and Environmental Studies, National Dong-Hwa University, No.1, Sec. 2, Da Hsueh Rd., Shoufeng, Hualien, 974, Taiwan, Republic of China

Photographs by the senior author.

**Abstract.**—The Brown Anole (*Anolis sagrei*) has become an invasive species in some parts of the Americas and in some localities in the Pacific region. In Taiwan, *A. sagrei* was recorded for the first time in 2000 in Santzepu, southwestern Taiwan, and was subsequently recorded in Chisintang, eastern Taiwan, during 2006. For future monitoring and research, we describe the known distribution of *A. sagrei* in Taiwan by plotting GPS coordinates of localities where *A. sagrei* was observed during surveys (conducted on an *ad hoc* basis since this species was first discovered in Taiwan) or where specimens have been collected on GIS User Community aerial photographs that were divided into 100 x 100-m grids. We recorded this invasive lizard in southwestern Taiwan in an area spanning approximately 237 ha and in an approximately 8-ha area in eastern Taiwan. Since *A. sagrei* is easily spread by human activities, and because not all areas could be thoroughly surveyed, we conclude that the current actual distribution of *A. sagrei* in Taiwan is probably more extensive than shown. We believe that the eradication of *A. sagrei* in Taiwan through removal is unrealistic, and propose that ongoing efforts should focus on managing this species.

**Keywords:** *Anolis sagrei*, Brown Anole, diffusion dispersal, nursery industry, saltation dispersal, Taiwan

The Brown Anole (*Anolis sagrei*; Fig. 1), also referred to as the Cuban Anole (Meshaka et al. 2004), is believed to have originated in Cuba, and subsequently dispersed to the Bahamas, parts of the Caribbean, and the Atlantic coast of México to Belize (Williams 1969; Schwartz and Henderson 1991; Rodriguez Schettino 1999). It also has become an invasive species in some parts of the world. Although evidence is equivocal that *A. sagrei* was introduced into Jamaica by anthropogenic activities as opposed to natural dispersal (J.B. Losos, pers. comm.), introduced populations of *A. sagrei* have been recorded in parts of the Americas as well as some localities in the Pacific region (Kraus 2009; Burgess 2012; Tan and Lim 2012). In Taiwan, *A. sagrei* was recorded for the first time in 2000 in Santzepu, Sheishan District, Chiayi County, southwestern Taiwan (Norval et al. 2002), and was subsequently recorded in Chisintang, Hualien County, eastern Taiwan, during 2006

(Chang 2007). To date, more than ten years after *A. sagrei* was first recorded, no descriptions about the known distribution of this species in Taiwan have been published. Therefore, for purposes of future monitoring and research, a description of the known distribution of *A. sagrei* in Taiwan is presented herein.

## Methods

Since the first records of *A. sagrei* as an invasive species in Taiwan until mid-2014, surveys were conducted on an *ad hoc* basis in areas where these lizards were potentially thought to occur. Because *A. sagrei* usually perches conspicuously on tree trunks and other objects in open sunny areas (Schwartz and Henderson 1991; Rodriguez Schettino 1999; Meshaka et al. 2004), the surveys usually entailed visually searching for active or basking animals in habitats likely to be used by these lizards. When *A. sagrei* or any other lizard was observed, we



**Fig. 1.** The Brown Anole (*Anolis sagrei*; adult female on the left and male on the right) is a diurnally active trunk-ground species usually found on the ground or on tree trunks and other objects rarely more than 1.5 m above the ground.

recorded the locality's GPS coordinates. Since these surveys were done to only determine the presence of *A. sagrei* in the various localities, lizards were not counted. In addition, localities where specimens of *A. sagrei* have been collected as part of ongoing research on this species in Taiwan were also incorporated into the distributional data collected during surveys. Using Arcview GIS8.3 GPS, GIS User Community aerial photographs of the study areas were divided into 100 x 100-m grids. The GPS coordinates of all the localities where *A. sagrei* has been recorded over the period of late-2001 to mid-2014 were used to plot grids in which these lizards were recorded to create current presence/absence distribution maps of the species in Taiwan. Conservative estimates of the distribution of this species in Taiwan were then made by counting the number of grids in which these lizards were recorded.

### Results

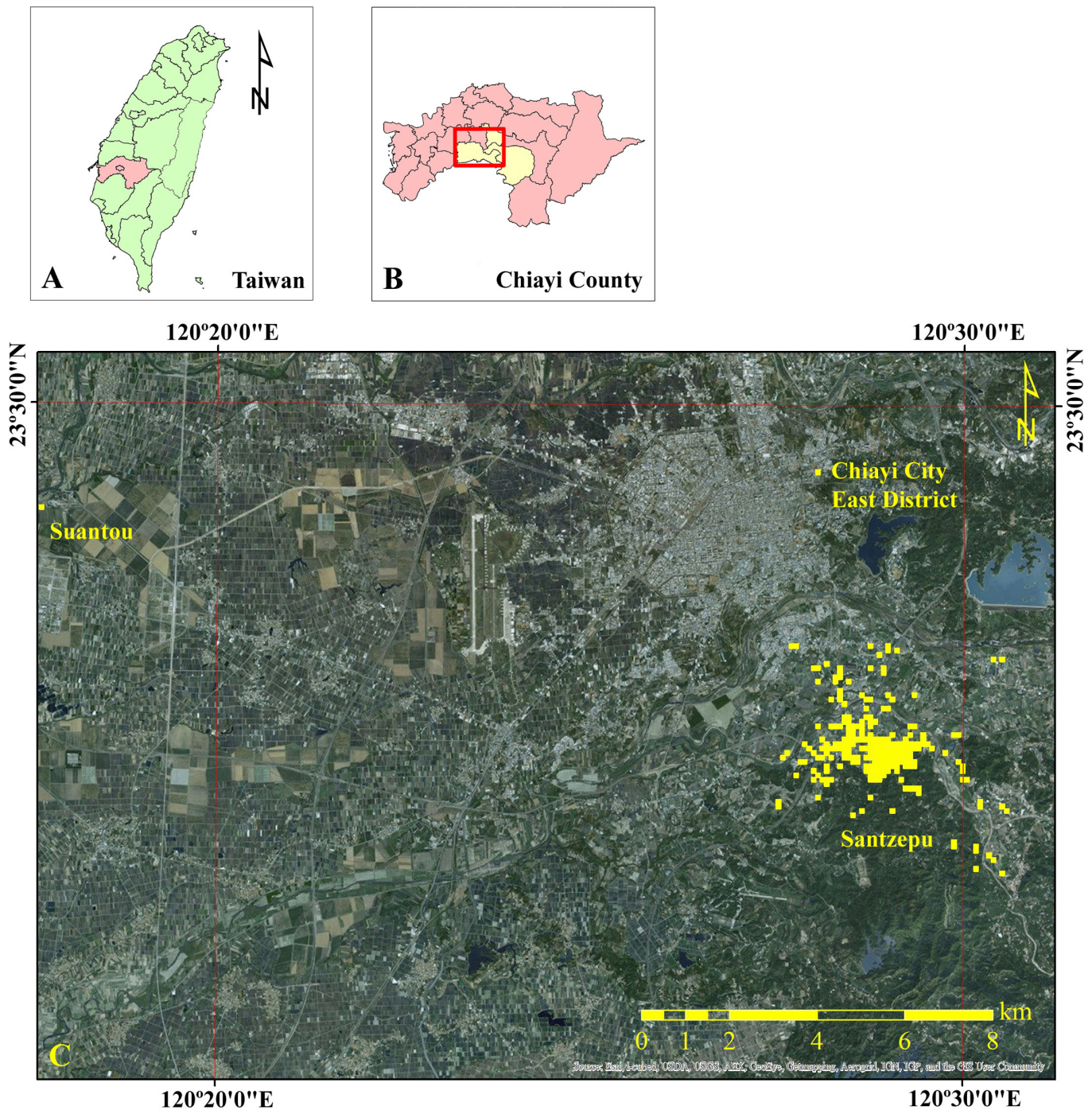
In the southwestern study site, *A. sagrei* was recorded in one locality in the East District of Chiayi City (Fig. 2). In Chiayi County, the species was recorded in one locality in Suantou (Liujiiao Township) and in numerous localities in the area in and surrounding Santzepu (Fig. 2). Lizards were recorded in

a variety of habitats, including roadside and urban gardens, parks, cemeteries, fruit orchards, and other agricultural fields.

At the eastern study site, *A. sagrei* was recorded in two localities in Chisintang, one near the Hualien Air Base, one along the Tunglan Cycling Trail, and two at National Dong-Hwa University, all in Hualien County (Fig. 3). They also were found in one locality in Biyunjuang Community and one in Nanhua Community, both in the outskirts of Hualien City (Fig. 3). Lizards were in urban gardens, fallow fields, coconut (*Cocos nucifera*) plantations, an area that is currently being developed into a stone sculpture park (to exhibit sculptures made from various rock types from Taiwan), and along the edges of roadside secondary forests.

### Discussion

Davis and Thompson (2000) termed dispersal of a species over widely distant environments, often separated by some barrier, as saltation dispersal, and short-distance dispersal to adjacent or nearly adjacent environments as diffusion dispersal. As the populations of *A. sagrei* in Taiwan continue to grow they can be expected to extend their distribution by spreading into suitable neighboring habitats (i.e., diffusion dispersal). Due to the

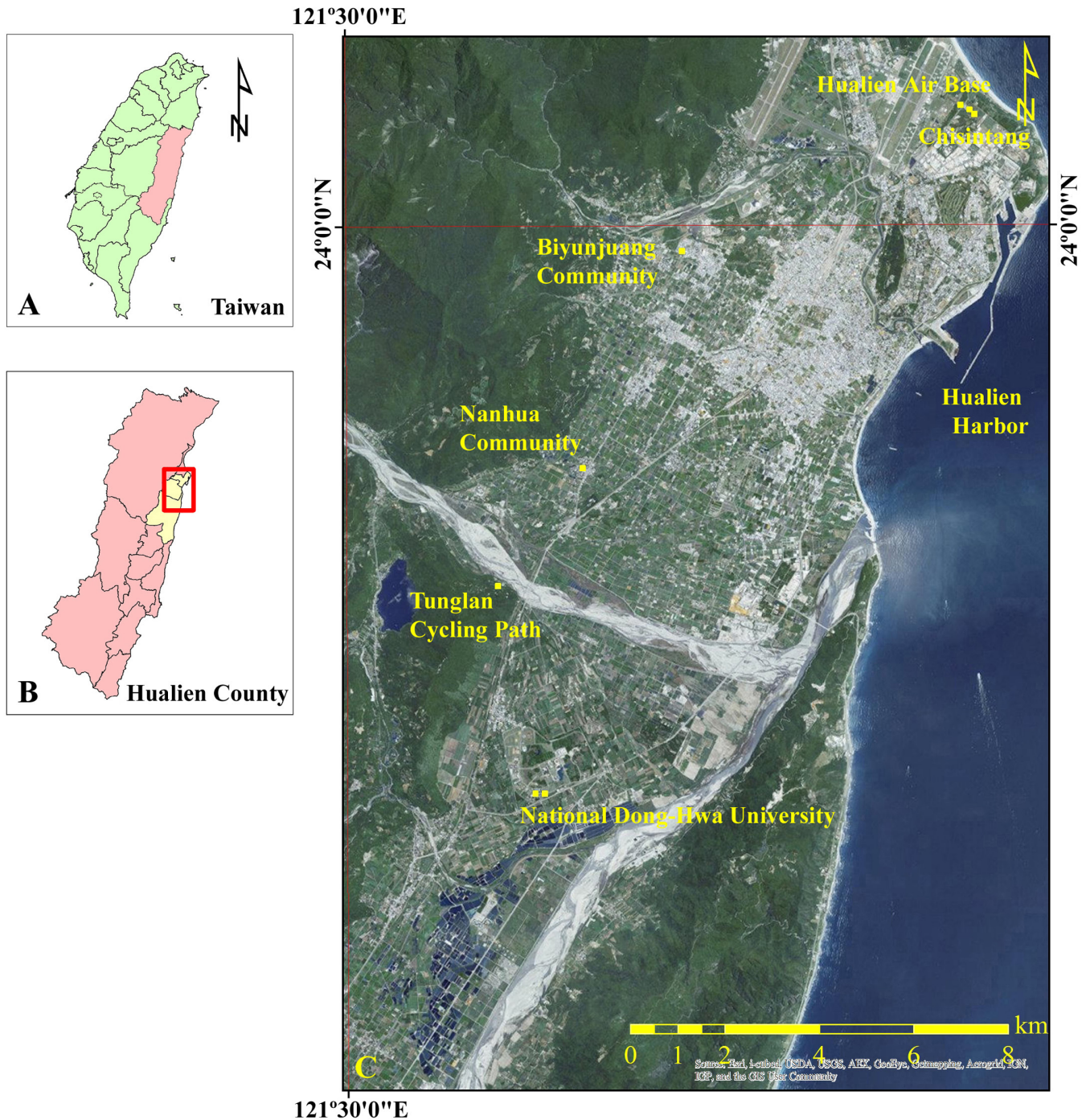


**Fig. 2.** Chiayi County, southwestern Taiwan (A), the study area (red rectangle in B), and the distribution of one-hectare plots (yellow squares) in which *Anolis sagrei* was recorded (C). Total area of distribution is ca. 237 ha. From Norval (2015).

species' small size, it easily hides among objects, and since *A. sagrei* is human commensal, these lizards are frequently transported intentionally and/or unintentionally to new localities by humans (Campbell 1996; Norval and Mao 2007; Kraus 2009). Consequently, *A. sagrei* is likely to spread further throughout Taiwan as a result of human-mediated saltation dispersal. A particularly likely agent in such events is the nursery industry. In various parts of its range, where *A. sagrei* is an invasive species, the nursery industry has been implicated in its dispersal

(Kraus 2009). Numerous small nurseries exist in Santzepu and surrounding areas, and *A. sagrei* has been observed among cultivated plants at some of these nurseries (e.g., Fig. 4; GN, pers. obs.). Thus the occurrence of these lizards in parks and urban gardens in Chiayi City, Hualien City, and Hualien County is likely a result of these lizards being introduced into these localities with plants from nurseries in areas invaded by *A. sagrei*.

Because *A. sagrei* is more than likely being introduced into new localities with nursery products and that some



**Fig. 3.** Hualien County, eastern Taiwan (A), the study area (red rectangle in B), and the distribution of one-hectare plots (yellow squares) in which *Anolis sagrei* was recorded (C). Total area of distribution is ca. 8 ha. From Norval (2015).

localities in Chiayi and Hualien Counties could not be surveyed because the areas belonged to religious groups that distrusted our surveys or could not be accessed because they were military facilities or private property, the current actual distribution of *A. sagrei* in Taiwan is likely more extensive than indicated. The description of the range herein is thus a conservative estimate and serves primarily as a basis for future studies.

Considering that most successful eradications of invasive species were confined to small islands (Zavaleta et al. 2001) and that the largest proportion of invasive species are those that exist in vacant niches and/or coexist with native species (Williamson 1999; Davis et al. 2011), Davis et al. (2011) argued that eradication efforts should be directed at those species that cause serious ecological and/or financial losses. In addition, where multiple invasive species coexist at different



**Fig. 4.** One of the numerous small nurseries located in Santzepu, Sheishan District, Chiayi County, southwestern Taiwan, and a Brown Anole (*Anolis sagrei*) observed among the plants (position indicated by the red arrow). From Norval (2015).

trophic levels, the eradication of one invasive species could lead to negative effects on populations of native species (Zavaleta et al. 2001). Furthermore, some native species might benefit from the presence of invasives, and the eradication of those invaders could negatively affect the native species (Davis et al. 2011). Consequently, management approaches with regard to invasive species should be based on scientific data and not necessarily on the origin of a species (Davis et al. 2011).

The eradication of *A. sagrei* in Taiwan is in our opinion unrealistic since its distribution is fairly extensive and the species readily disperses. Efforts instead should focus on managing this species. The conservation of native lizards in urban and rural areas in Taiwan requires special attention, because species such as the Long-tailed Skink (*Eutropis longicaudata*), Swinhoe's Tree Lizard (*Japalura swinhonis*), and the Elegant Skink (*Plestiodon elegans*), which can be human commensals, can be instrumental in mitigating the impact of *A. sagrei* on native ecosystems by competing with or preying on these invasive lizards (Norval et al. 2004; Norval et al. 2012a; Norval et al. 2012b).

Since we have noted that broadleaf forests in Taiwan appear to be unsuitable habitats for *A. sagrei* (Wang 2013; Norval 2015), we recommend that greater efforts should be made to re-establish and conserve large areas of broadleaf forests in disturbed lowland areas of Taiwan. This would not only contribute to the conservation of indigenous forest species, but such areas also could function as reservoirs for species like *J. swinhonis* that can compete with *A. sagrei* and serve as barriers to its spread.

In view of its great potential to spread to new territories and to prevent future introductions of *A. sagrei* into new localities, we recommend drastic steps, including the quarantining of newly imported cargos originating from areas

where this lizard is known to occur. Ports and harbors, such as Hualien harbor, should be surveyed regularly, and if *A. sagrei* is noted in such localities, actions, such as intensive capturing and exclusion barriers, like those constructed to prevent the spread of the Green Anole (*Anolis carolinensis*) in the Ogasawara Islands of Japan (Toda et al. 2010), should be taken to minimize the risk of these lizards dispersing to new localities.

#### Acknowledgements

The authors express their gratitude to Liudmila Ivanova, Hao Su, and Hui-Hsuan Yang for assistance with fieldwork, and to Shao-Chang Huang for obtaining some references. Clearance for the research presented herein was granted by the Research Ethics Review Committee of the College of Agriculture and Environmental Sciences of UNISA (clearance certificate number: Ref. Nr.: 2013/CAES/022) and the National Ilan University Animal Ethics Committee (clearance certificate number: 100-26).

#### Literature Cited

- Burgess, J. 2012. Cuban Brown Anoles (*Anolis sagrei*) in the Turks & Caicos Islands. *Reptiles & Amphibians* 19: 263–264.
- Campbell, T.S. 1996. Northern range expansion of the Brown Anole (*Anolis sagrei*) in Florida and Georgia. *Herpetological Review* 27: 155–157.
- Chang, N.C. 2007. A new discovered alien lizard of Hualien – *Anolis sagrei*. *Quarterly of Natural Conservation* 57: 37–41 (in Chinese).
- Davis, M.A., M.K. Chew, R.J. Hobbs, A.E. Lugo, J.J. Ewel, G.J. Vermeij, J.H. Brown, M.L. Rosenzweig, M.R. Gardener, S.P. Carroll, K. Thompson, S.T.A. Pickett, J.C. Stromberg, P. Del Tredici, K.N. Suding, J.G. Ehrenfeld, J.P. Grime, J. Mascaro, and J.C. Briggs. 2011. Don't judge species on their origins. *Nature* 474: 153–154.
- Davis, M.A. and K. Thompson. 2000. Eight ways to be a colonizer; two ways to be an invader. *Bulletin of the Ecological Society of America* 81: 226–230.
- Kraus, F. 2009. *Alien Reptiles and Amphibians: A Scientific Compendium and Analysis*. Springer, Dordrecht, The Netherlands.

- Meshaka, W.E. Jr., B.P. Butterfield, and J.B. Hauge. 2004. *The Exotic Amphibians and Reptiles of Florida*. Krieger Publishing Company, Malabar, Florida.
- Norval, G. 2015. The morphology, reproductive biology and habitat utilisation of the exotic invasive lizard, the brown anole (*Anolis sagrei*), in Taiwan. Unpublished master's dissertation, University of South Africa, South Africa.
- Norval, G. and J.J. Mao. 2007. Can *Anolis sagrei* be unintentionally transported to new localities in bamboo stem bundles? *Sauria* 29: 51–54.
- Norval, G., J.J. Mao, H.P. Chu, and L.C. Chen. 2002. A new record of an introduced species, the Brown Anole (*Anolis sagrei*) (Duméril & Bibron, 1837), in Taiwan. *Zoological Studies* 41: 332–336.
- Norval, G., J.J. Mao, and H.P. Chu. 2004. *Mabuya longicaudata* (Long-tailed Skink). Predation. *Herpetological Review* 35: 393–394.
- Norval, G., S.C. Huang, J.J. Mao, S.R. Goldberg, and K. Slater. 2012a. Additional notes on the diet of *Japalura swinhonis* (Agamidae), from southwestern Taiwan, with comments about its dietary overlap with that of sympatric *Anolis sagrei* (Polychrotidae). *Basic and Applied Herpetology* 26: 87–97.
- Norval, G., J.J. Mao, and K. Slater. 2012b. A description of an observed interaction between an Elegant Skink (*Plestiodon elegans* [Boulenger, 1887]) and a Brown Anole (*Anolis sagrei* Duméril & Bibron, 1837) in southwestern Taiwan. *Herpetology Notes* 5: 189–192.
- Rodriguez Schettino, L.R. 1999. *The Iguanid Lizards of Cuba*. University Press of Florida, Gainesville.
- Schwartz, A. and R.W. Henderson. 1991. *Amphibians and Reptiles of the West Indies: Descriptions, Distributions, and Natural History*. University Press of Florida, Gainesville.
- Tan, H.H. and K.K.P. Lim. 2012. Recent introduction of the Brown Anole *Norops sagrei* (Reptilia: Squamata: Dactyloidae) to Singapore. *Nature in Singapore* 5: 359–362.
- Toda, M., H. Takahashi, N. Nakagawa, and N. Sukigara. 2010. Ecology and control of the Green Anole (*Anolis carolinensis*), an invasive alien species on the Ogasawara Islands, pp. 145–152. In: K. Kawakami and I. Okochi (eds.), *Restoring the Oceanic Island Ecosystem. Impact and Management of Invasive Alien Species in the Bonin Islands*. Springer-Verlag Tokyo, Springer Japan, Tokyo.
- Wang, G.Q. 2013. Modeling the dispersal pattern of Brown Anole (*Anolis sagrei*) population in Samtzepeu, Chiayi County, Taiwan. Unpublished master's dissertation, National Cheng Kung University, Tainan, Taiwan, R.O.C.
- Williams, E.E. 1969. The ecology of colonization as seen in the zoogeography of anoline lizards on small islands. *The Quarterly Review of Biology* 44: 345–389.
- Williamson, M. 1999. Invasions. *Ecography* 22: 5–12.
- Zavaleta, E.S., R.J. Hobbs, and H.A. Mooney. 2001. Viewing invasive species removal in a whole-ecosystem context. *Trends in Ecology and Evolution* 16: 454–459.