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The continuing march of Common Green Iguanas: arrival on mainland Asia

Matthijs P. van den Burg[a,*], Steven M. Van Belleghem[b], Christina N. De Jesús Villanueva[c,d]

[a] Department of Biogeography and Global Change, Museo Nacional de Ciencias Naturales, Spanish National Research Council (CSIC), c/ José Gutiérrez Abascal 2, 28006 Madrid, Spain
[b] Department of Biology, University of Puerto Rico, Río Piedras, San Juan, Puerto Rico
[c] College of Environmental and Life Science. University of Rhode Island, Kingston, Rhode Island, USA
[d] International Institute of Tropical Forestry, United States Forest Service, United States Department of Agriculture, San Juan, Puerto Rico

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ABSTRACT

The popularity of the Common Green Iguana (*Iguana iguana*) as a pet has contributed to its global occurrence as an invasive alien species. Early detection and control of alien *I. iguana* populations is necessary to prevent the need for large and financially demanding eradication actions. Here, we first collated information from digital footage and interviews regarding sightings of free roaming *I. iguana* specimens in Singapore and Thailand. We use this information to report and discuss an ongoing invasion with early stage establishment being facilitated by release of pets and escape from recreational parks, as well as the resulting conservation implications. Using species-distribution modeling to assess the potential distribution in Southeast Asia, we identify large regions with suitable habitat that could aid the expansion of these alien populations in the absence of future control measures. In addition, given the availability of suitable habitat throughout the Philippine archipelago and its high number of imported iguanas and within-country trade, we call for awareness of future alien *I. iguana* populations in the Philippines. Next, the alien population in Singapore is of additional concern given that the excellent swimming capacity of *I. iguana* allows it to reach neighboring Sumatra and > 3,000 islands of the Indonesian Riau archipelago. Finally, we report *I. iguana* sightings in Hong Kong and Peninsular Malaysia. We provide strategy recommendations for implementing mitigation efforts and to halt future release and spread in order to prevent negative biodiversity impacts associated with a large invasive alien *I. iguana* population.

1. Introduction

The Common Green Iguana (*Iguana iguana*, Linnaeus, 1758) is a heavily traded reptilian pet species that has seen its global transport regulated since 1977 (CITES, 2019). In fact, the pet trade is the most important contributor to the origin of non-native populations of green iguanas (Bock, Malone, Knapp, & Aparicio, 2018; Falcón, Ackerman, Recart, & Daehler, 2013; Kraus, 2009), although invasions have also been aided through over-water dispersal following hurricanes and subsequent post-hurricane relief efforts (Censky, Hodge, & Dudley, 1998; van den Burg, Brisbane, & Knapp, 2020). *Iguana iguana* is native throughout Central and South America as well as on several Caribbean islands (Stephen, Reynoso, Collett, & Hasbun, 2013; Bock et al., 2018). Invasions of *I. iguana* are mainly restricted to Caribbean islands and Florida (USA), with only a small set of islands known from outside this region: Fiji, Hawaii (USA), Japan (Ishigaki island), and Taiwan (Bock et al., 2018; Lee, Chen, Shang, & Clulow, 2019). Importantly, established populations of this invasive alien species (IAS) have so far not been successfully eradicated (Lee et al., 2019; Rivera-Milán & Haakonsson, 2020), though several efforts are currently underway (e.g. Dominica and Fiji).

The rapid growth of *I. iguana* populations can pose a threat to the economy of invaded territories, through infrastructure damage and agricultural loss, as well as threats to biodiversity (Bock et al., 2018; Falcón et al., 2013). As alien populations can originate from multiple genetic lineages (Stephen, Reynoso, Collett, Hasbun, & Breinholt, 2013; van den Burg, Meirmans et al., 2018) high genetic diversity might increase adaptive variation to persevere in non-native environments, as seen for other non-native lizards (e.g., Kolbe et al., 2004). It has been suggested that the growth of non-native *I. iguana* populations is aided by the low number of predators and direct competitors (López-Torres, Claudio-Hernández, Rodríguez-Gómez, & Longo, 2011); however, this and other hypotheses on the growth of these populations remain untested (e.g., lack of parasites, high food abundance, enemy-release

* Corresponding author.
E-mail address: thijs.burg@gmail.com (M.P. den Burg).

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hypothesis). Furthermore, non-native *I. iguana* populations are a threat to native species through direct physical and hierarchical competition and hybridization (Vuillaume, Valette, Lepais, Grandjean, & Breuil, 2015; Moss et al., 2017; van den Burg, Breuil, & Knapp, 2018; van Wagensveld & van den Burg, 2018). On Grand Cayman, an island of 196 km^2, the present invasive *I. iguana* population was estimated to reach between 0.9–1.9 million individuals in early 2018 before the start of a government-financed culling program (Rivera-Milán & Haakonsson, 2020). During this program's initial year, through collective work of 500 hunters, over 960,000 iguanas were removed at the expense of 5.7 million USD (Rivera-Milán & Haakonsson, 2020). As the successful eradication of *Eleutherodactylus coqui* on O'ahu (Hawai'i) (Beachy, Neville, & Arnott, 2011) demonstrated, preventing further spread of IAS and the need for multimillion-dollar population-reduction or eradication programs depends on key rapid management action during the introduction and establishment phases (Davis, 2009; Blackburn, Pyšek, & Bacher, 2011).

In Southeast Asia, Thailand and Singapore are considered important hubs in the international wildlife trade (Nijman, 2010). In these countries, herpetofaunal survey reports identified notable discrepancies among CITES import data and the presence of several non-native species in the wild (Nijman & Shepherd, 2007, 2010, 2011; Yeo & Chia, 2010; Poole & Shepherd, 2017). For Thailand, Nijman and Shepherd (2011) found that over 150 distinct non-native species of amphibians and reptiles had CITES import records between 1990–2007. In contrast, only two alien reptile species (*Trachemys scripta elegans* and *I. iguana*) were recorded in Thailand during a 2011–2012 inventory of wild alien vertebrate fauna (Boonkuaw, Kanchanasaka, & Prayoon, 2014). For *I. iguana*, Boonkuaw et al. (2014) reported three sightings of single specimens in Thailand, all of which had disappeared before the report's publication. Singapore is mainly regarded as an import and re-export country (Nijman, Todd, & Shepherd, 2012) and was the main regional reptile importer between 1998–2007 (Nijman, 2010). In contrast to Thailand, over 20 alien reptile species were present in Singapore in 2010 (Ng & Lim, 2010; Yeo & Chia, 2010). Of these species, only four were considered established (*Calotes versicolor*, *Pareas margaritophorus*, *Siebenrockiella crassicollis* and *Xenochrophis vittatus*); with *I. iguana* only known from a few recordings (Chua, 2007; Yeo & Chia, 2010). However, despite previous reports of few *I. iguana* specimens (Boonkuaw et al., 2014; Yeo & Chia, 2010), recent reports of free-roaming *I. iguana* on social media platforms (e.g. FaceBook and Instagram) and on iNaturalist have sparked our concern over the potential for established and growing invasive alien populations to be present in Singapore and Thailand.

Here, we 1) summarize the current extent of *Iguana iguana* in Singapore and Thailand, 2) identify locations with signs of early establishment and its facilitators, 3) predict the potential range in the absence of future eradication action, and 4) provide recommendations to prevent future releases and mitigate negative ecological effects.

2. Methods

2.1. Observations

We traced the presence of alien *I. iguana* in Singapore and Thailand through verifiable sightings using photographs and videos from social media (FaceBook and Instagram), Internet websites (www.flickr.com, www.istockphoto.com, www.shutterstock.com) and iNaturalist. On iNaturalist we also reviewed sightings from other Southeast Asian countries. We contacted and interviewed owners of online images whose content suggested the presence of free-roaming *I. iguana* to acquire more details including the location where the picture was taken, date, presence of free-roaming *I. iguana*, presence of different *I. iguana* life stages and number of individuals present. Through snowball sampling (where interviewees had more footage or contacts with similar footage) we were able to acquire additional verifiable sightings not publicly available. When images were taken within zoos or recreational parks (hereafter recreational parks) we asked whether *I. iguana* were kept in holding cages or were freely roaming. In the latter case, we recorded these facilities as potential sources for current and future alien populations.

2.2. Suitable habitat modeling

Species distribution modeling is generally used to identify the climatic niche of a species using available climatic data retrieved from observation record locations. This method has been broadly implemented to predict the potential distribution of both native and alien species (e.g. Srivastava, Griess, & Keena, 2020), as well as for future climate scenarios (Velásquez-Tibatá, Salaman, & Graham, 2013). Previously this method has also been applied to *Iguana iguana* (Falcón et al., 2013), although elevation data − an important abiotic variable that limits this species presence and distribution (Stephen et al., 2013) − were not included in the model.

To understand the potential range of *Iguana iguana* in Southeast Asia, we used MaxEnt (Philips, Dudík, & Schapirem, 2018) as implemented in the *dismo* R package (Hijmans, Phillips, Leathwick, & Elith, 2017; R Core Team, 2019) to build species distribution models (SDM), for current and future climate scenarios. Specifically, it allows us to identify the potential Southeast Asian range of *I. iguana* in the absence of mitigation actions and identify those areas where viable populations are most likely to occur. MaxEnt uses environmental and climatic data from species-occurrence localities to build a predictive SDM of habitat suitability (HS) for the study species, which runs between 0 (low suitability) and 1 (high suitability).

We acquired *I. iguana* occurrence data uploaded to the Global Biodiversity Information Facility (GBIF.org, 2019), and observations of free-roaming iguanas from Thailand and Singapore through iNaturalist. We retained occurrence data from established alien populations where breeding occurs, arguing that, although non-native areas can hold different climatic compositions compared to native areas, local climatic variables are suitable for successful reproduction and thus help to generalize intraspecific variation within the *I. iguana* complex (Elith, Kearney, & Phillips, 2010; Briscoe Runquist, Lake, & Tiffin, 2019). We filtered data records based on georeference inaccuracy (excluded when > 50 km), added records collected during recent fieldwork by the authors (for Colombia and Puerto Rico) and from recent publications on non-native populations (Kraus, 2019; Lee et al., 2019). We also included locations in Singapore and Thailand where hatchling or juvenile *I. iguana* have been observed which indicates ongoing breeding (see above). We removed duplicated locations and erroneous records from locations without *I. iguana* breeding populations (e.g. Galapagos) and with altitude records outside of the species range (> 1000 meters; Stephen et al., 2013). Remaining records were then filtered to retain only one record per 50 km^2 (Boria, Olson, Goodman, & Anderson, 2014) to remove distribution skewness in locality data (particularly high for Central America), leaving a total of 423 records for final model construction (Fig. A1, Supporting Information).

The initial SDM was built using uncorrelated WorldClim 2.0 bioclimatic variables and altitude layer (Fick & Hijmans, 2017; at 2.5 arc-minutes resolution). As correlation between variables can lead to overfitting, we implemented the *vifstep* function within the *sdm* package (Naimi & Araújo, 2016). This stepwise process identifies the variance inflation factor (VIF), a measure for each variable of how much it can be explained by the others, and removes those with high VIF values (here set to 10; Chatterjee & Hadi, 2006). After stepwise filtering, 10 variables were retained for the final model with a 2.0–9.1 range of remaining VIF scores: mean diurnal range (BIO2), isothermality (BIO3), mean temperature of wettest quarter (BIO8), mean temperature of driest quarter (BIO9), precipitation of wettest month (BIO13), precipitation of driest month (BIO14), precipitation seasonality (BIO15), precipitation of warmest quarter (BIO18), precipitation of coldest quarter (BIO19), and altitude.

Bioclimatic and occurrence data were next combined to build a SDM using MaxEnt (Philips et al., 2018) under a current climate scenario. This model was generated for mainland Southeast Asia as well as the Philippines, given the high prevalence of *I. iguana* footage there and apparent within-country trade observed on social media platforms. Model performance was evaluated using the area under the curve summary statistic (AUC) with one-tenth of the data; AUC values of $\geq$ 0.90 indicate high model performance (Swets, 1988). A set of 10 SDM replications were run with 80% of records used for model training and 20% for model testing, using pseudo-absence records (sampled 10,000 random points) close to presence records (Barbet-Massin, Jiguet, Albert, & Thuiller, 2012; Philips & Dudík, 2008). Given the large distribution of *I. iguana*, we implemented a point-wise sample technique for pseudo-absence points (Hijmans, 2012) as incorporated in the *dismo* package (Hijmans et al., 2017). The HS absence threshold was determined from the training specificity and sensitivity as implemented in the *dismo* package (Hijmans et al., 2017) as it outperforms other indices (Allouche, Tsoar, & Kadmon, 2006). Predictions of HS for a future climate scenario were run for 2041-2060 using the MIROC6 model and 245 shared socioeconomic pathways (Eyring et al., 2016; Fick & Hijmans, 2017).

3. Results

For Thailand, sighting information was collected from contact with 15 persons and iNaturalist for records since 2016. Sightings originated from a total of 12 locations distributed throughout most of Thailand (Fig. 1), with a minimum number of total sightings of 97 *I. iguana* (Table A1, Supporting Information). Adult or subadult life stages were observed at all locations, whereas hatchling or juvenile life stages occurred at four. The highest number of sightings by different observers was found around Nakhon Ratchasima town in Nakhon Ratchasima Province. Locations with the highest number of unique *I. iguana* were Nakhon Si Thammarath and Ubonrat, and in the Uthai Thani district. Lastly, at least four recreational parks exhibit non-caged *I. iguana*: Chai Nat Bird Park, Chiang Mai Night Safari, Nakhon Ratchasima Zoo, and Tha Lat Bird Park.

For Singapore, sighting information was collected from iNaturalist records, contact with 10 persons, and seven literature publications since 2007 (Chew & Low, 2017; Chua, 2007; Khoo, 2016; Ng & Lim, 2015; Tay, 2015; Yeo, 2014, 2019). We recorded a minimum of 50 *I. iguana* sightings from 17 locations in Singapore (Fig. 1), of which five locations showed presence of hatchlings and/or juveniles. The highest number of *I. iguana* sightings came from the area surrounding Jurong hill and Jurong Bird Park as well as around the Warren Golf & Country Club. Recreational parks were not found to exhibit free-roaming *I. iguana* in Singapore.

Besides free-roaming *I. iguana* records from Singapore and Thailand, we recorded two additional locations in Southeast Asia. First, one free-roaming adult *I. iguana* was observed southeast of Kuala Lumpur, Peninsular Malaysia; this animal was caught in the yard of the observer and was released in an area nearby. The second record is from two free-roaming adult iguanas adjacent to the Tsing Tam Reservoirs in Hong Kong.

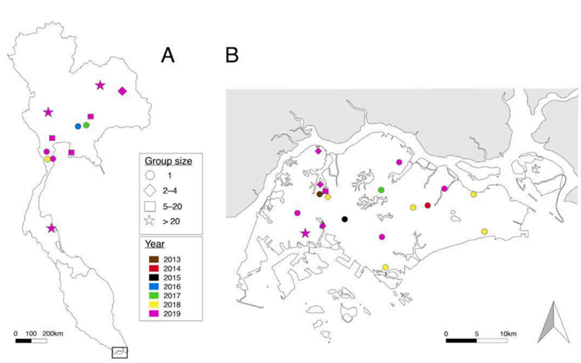

Fig. 1. Localities with presence of *Iguana iguana* in (A) Thailand and (B) Singapore showing number of iguanas and year of sighting. Color of the most recent year is displayed per location.

Species-distribution modeling for both current and future climatic conditions suggests the presence of substantial areas with habitat suitable for *I. iguana* in Thailand and surrounding countries (Fig. 2 and Fig. A2, Supporting Information). Suitable habitat is especially widespread in mainland regions below 15 degrees latitude, except for some areas in Thailand, south and central Peninsular Malaysia, and non-coastal regions in Vietnam. Several higher-latitude regions have suitable habitat as well, including parts of the Gulf of Martaban, and lower-elevation areas in Thailand, southern Laos, and central Vietnam. Under a 2050 climate scenario, the presence of suitable habitat in northern latitudes (above 14 degrees) is projected to decrease (Fig. A2, Supporting Information). All *I. iguana* locations reported here below 14 degrees latitude are in high HS areas, with those at higher latitudes in areas with marginal or low HS, except for the Uthai Thani district (Fig. 2). For the Philippines, the current climate model identified suitable habitat in lowland areas on all major islands and marginal habitat or absence of suitable habitat for higher elevations. The median AUC for 10 SDM replications for the constructed model was 0.955 (50% interquartile ranges of 0.953–0.957), with a median HS absence threshold of 0.20 (0.16–0.23). Percent contribution of altitude and WorldClim variables, as median over 10 runs, was: 1 (BIO2), 36 (BIO3), 1.6 (BIO8), 1.8 (BIO9), 28.9 (BIO13), 2 (BIO14), 4.4 (BIO15), 0.6 (BIO18), 0.9 (BIO19), and 21.2 (altitude).

4. Discussion

We report *I. iguana* invasions and establishment in both Singapore and Thailand with details about present life stages as well as the current and potential future distribution. In both countries, the presence of

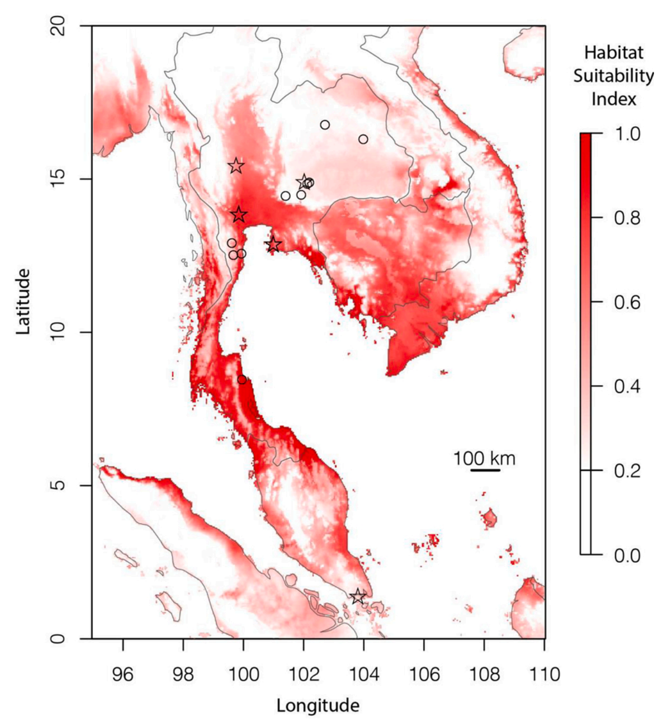

Fig. 2. Species distribution models for *Iguana iguana* in Singapore, Thailand and surrounding countries. Models used an absence threshold of 0.20 and habitat suitability ranges from high (dark red) to low (white). Circles represent locations with *I. iguana* presence, stars locations where juvenile and/or hatchling life stages were present.

hatchling and/or juvenile life stages is of heightened conservation concern as it indicates local recruitment and ongoing establishment of this known invasive alien species. Importantly, this report describes the second recorded mainland establishment of *I. iguana* (after Florida, USA) and increases the number of known non-western-hemisphere establishments to six: Fiji, Hawaii, Japan (Ishigaki island), Singapore, Taiwan and Thailand (Engeman, Jacobson, Avery, & Meshaka, 2011; Falcón et al., 2013; Kraus, 2019; Lee et al., 2019; Mito & Uesugi, 2004); though updates on the status of the Japanese and Hawaiian populations are necessary. Following interviews, we identified the likely source of these invasions to be pet-trade animals that either escaped or were intentionally released by owners or unsecurely exhibited in recreational parks, consistent with other introductions of this species (Kraus, 2009). Besides the release of pet *I. iguana* due to their size, another motive can be fang sheng; the Buddhist act of releasing live animals believed to build spiritual merit (Agoramoorthy & Hsu, 2005; Ng & Lim, 2010). As *I. iguana* natively occurs in sub-tropical and tropical biomes physically and climatically similar to those found throughout Southeast Asia (Olson, Dinerstein, Wikramanayake, & Burgess, 2001), we expect continued spread and growth of these alien populations in the absence of mitigation actions. Indeed, our current and future climate SDMs indicate that large areas in the region have highly suitable *I. iguana* habitat. Given this species' exceptional over-water dispersal abilities (Breuil, 1999; Censky et al., 1998; van Veen, 2011; F. Kraus, pers. comm. 2020), a large number of novel locations with suitable habitat could be reached from Singapore (Fig. 2): Peninsular Malaysia, Sumatra, and > 3,000 islands of the Indonesian Riau archipelago. In the absence of removal actions, the persistence and uncontrolled growth of *I. iguana* populations is likely inasmuch as numerous locations are within highly suitable habitat and recruitment is present (Fig. 2). The case presented here calls for management action because 1) establishment still appears to be in an early phase in several areas, 2) eradication expenses are relatively low during this stage of establishment, 3) current records are likely an underestimate inasmuch as data were collected opportunistically by non-iguana specialists, 4) a large uncontrolled *I. iguana* population could have far-reaching consequences for native biodiversity and agriculture.

Although the SDM model identified extensive presence of areas in Thailand with high HS, we note that several iguanas have been observed in areas identified with extremely low habitat suitability. We discuss three reasons that can explain this apparent mismatch between model performance and field sightings. First, as these records represent released non-native pets, their presence merely suggests that local climatic conditions are not directly lethal, with the potential for iguanas to remain alive in absence of extreme climate swings. Secondly, niche-width evolution is known to occur in alien populations (Urbanski et al., 2012), see Guisan, Petitpierre, Broennimann, Daehler, and Kueffer (2014)) for an overview. Lastly, local patches of suitable habitat, like small streams with some riparian forest, could be too small to influence SDM cell values. Data from future surveys will allow us to discriminate between these explanations and further improve our understanding of this species' ecological niche in Southeastern Asia.

Knowledge of the invasion pathway and source of alien populations is important to prevent both repetitive unintentional or purposeful incursions. Although *I. iguana* is native to the American tropics, their importation, captive breeding and escape or release practices could lead to unmanageable population growth in Southeast Asia. Between 2000 and 2017, a total of 1,254 live *I. iguana* were imported into Thailand (importer reported quantity; CITES, 2019), though currently the number of iguanas present could arguably be higher due to in-country captive-breeding practices as well as known import discrepancies in CITES reporting (Nijman & Shepherd, 2011). For Singapore, 542 live specimens were reported by importers before 2004 (CITES, 2019), with no records since, likely due to the country's ban on iguana-pet ownership. Several interviewees stated that either they themselves or others (i.e., iguana farms, recreational parks or private residence) have released captive iguanas. This was in addition to deliberate release statements by social media users. Increasing public awareness of the negative effects from IAS populations may help to discourage future releases.

Uncontrolled or flawed exhibition practices of animals can lead to their escape. For Spanish zoos, Fàbregas, Guillén-Salazar, and Garcés-Narro (2010)) identified that enclosure security was not sufficient to prevent escape in 14 % of assessed enclosures, mainly for enclosures holding alien species, which might source IAS populations. As those records concerned official zoos, the percentage of insufficient enclosures is likely to be higher in unofficial establishments as well as in privately owned collections. For Thailand, based on the presence of free-roaming iguanas near Thai recreational parks where non-caged iguanas are exhibited, these facilities are the most likely sources of iguanas reported in at least two areas: Nakhon Si Thammarath and Nakhon Ratchasima. In Singapore, although we did not acquire information about recreational parks that exhibit free-roaming iguanas, the grounds of one park (Jurong Bird Park) are invaded by iguanas. Anecdotal evidence suggests that their presence in the park and surrounding areas originates from the former neighboring reptile recreational park (Jurong Reptile Park). In addition to the risk of escape from parks, free-roaming *I. iguana* within recreational parks are reproductively unhindered, which leads to nesting and successful recruitment. From such nests, small free-roaming hatchlings emerge capable of establishing off-ground populations. This poses a particular detection challenge. In addition to their small size, the lizards' green coloration allows them to inconspicuously blend in with the foliage, evading detection for at least the first year of their development. In contrast to adults, these hatchlings are harder to catch and track because of their small size and capacity to disperse > 200 m within one month after hatching (Knapp & Abarca, 2009).

With little information available for Asian *I. iguana* introductions, it is not possible to make straightforward predictions about the ecological impacts of these novel establishments. Data from the Western Hemisphere demonstrate the possibility that established populations can spread pet-trade diseases to native species (Hellebuyck et al., 2017), competitively displace native species (van den Burg, Breuil et al., 2018), and cause erosion and damage to agricultural fields, horticultural plantings, roads and airstrips (Engeman, Smith, & Constantin, 2005; Krysko, Enge, Donlan, Seitz, & Golden, 2007; López-Torres et al., 2011). In Thailand, we note that alien *I. iguana* populations could have the capacity to displace *Physignathus cocincinus*, the Chinese water dragon (IUCN status Vulnerable; Stuart, Sumontha, Cota, & Panitvong, 2019), given the smaller maximum snout-vent length (SVL) of *P. cocincinus* and since it also prefers to resides close to streams (Stuart et al., 2019). Further, hatchling iguanas will likely be preyed upon by numerous native species, especially by many snakes given their high regional diversity (Chan-Ard, Parr, & Nabhitabhata, 2015), though predators for adult *I. iguana* (which can reach > 45 cm SVL) are fewer (e.g., large *Python bivittatus* or *Malayopython reticulatus* [Low, Bickford, Tan, & Neves, 2016], and birds of prey and mammals [Bock et al., 2018]). Additionally, *I. iguana* might compete with native species for territory through dominance display and aggression (Chua, 2007) and nesting sites (e.g. *Varanus* sp.). However, data on the reproductive cycle of *I. iguana* in Singapore and Thailand are currently lacking, making reproductive-period comparisons with native species difficult. Nevertheless, social media and press images of mating iguanas as well as a laid developed egg from Singapore suggest mating occurs around August–December (The Strait Times, 2017; J. Chiew pers. obs.).

Ongoing debate over the impact of green iguanas in natural areas continues in the absence of rigorous studies. In mangrove stands along a canal in Puerto Rico, over 80% of mangrove plants along the edge were damaged by alien *I. iguana* (Carlo & García-Quijano, 2008; López-Torres, Claudio-Hernández, Rodríguez-Gómez, Longo, & Joglar, 2012). Inland mangrove stands appeared less inhabited however (García-Quijano, Carlo, & Arce-Nazario, 2011), which could make narrow mangrove stands, like those found throughout Singapore more vulnerable to *I. iguana* impact (Yee, Ang, Teo, Liew, & Tan, 2011). Mangroves are globally threatened and in decline (Polidoro, Carpenter, Collins, &

Duke, 2010), and in Singapore (Friess & Webb, 2013), despite a recent minor restoration (Lai, Loke, Hilton, Bouma, & Todd, 2015), alien *I. iguana* may be expected to aggravate the decline of Singapore's mangroves. Recorded *I. iguana* presence in Singapore's Sungei Buloh Wetland Reserve is therefore worrisome. Future surveys and monitoring are necessary to better understand the ecological and economic impact of *I. iguana* establishment in Singapore and Thailand.

As the global pet trade has facilitated the spread of *I. iguana*, understanding global and local trade dynamics might aid the prediction of future invasions (Lockwood, Welbourne, Romagosa, & Cassey, 2019; Robinson, Griffiths, St John, & Roberts, 2015). Although the global *I. iguana* trade peaked in the early 2000's (Stephen et al., 2011; van den Burg & Weissgold, in press), the import of live *I. iguana* to Asia was highest in 2015, and a clear decline is absent (Fig. A3, Supporting Information). We propose that this stable trend is partially due to lower shipping costs and a growing Asian middle class (Kharas, 2017). On a regional level we note that in addition to Thailand, the Philippines have imported high numbers of green iguanas (CITES, 2019; Sy, 2015) and has an active within-country market based on social-media trade groups with thousands of followers and daily notes of requests and availability. Following these data, as well as the presence of large areas with high habitat suitability (Fig. A4, Supporting Information), we predict the (future) occurrence of additional invasive alien *I. iguana* populations within Asia, specifically in the Philippines. Lastly, the records of adult free-roaming *I. iguana* from Peninsular Malaysia and Hong Kong are cause for concern as well. Future assessments should identify whether these are isolated cases or not.

Assertive rapid action is required to halt the spread and successfully remove alien *I. iguana* populations before they become invasive. To that end we echo the recommendations of global experts (IUCN SSC Iguana Specialist Group, 2017) and provide additional monitoring suggestions. First, we recommend a complete ban on future *I. iguana* import and within-country trade, or at least increased strict regulation, with additional enforcement of exhibition rules. Secondly, we recommend the immediate implementation of survey and questionnaire efforts, through a multi-organizational approach, to better understand *I. iguana* distribution in Singapore and Thailand. Thirdly, acquired distribution data should be used to design an action plan with the objective to remove alien *I. iguana* populations, co-designed and advised by species experts.

Conflict of Interest

The authors declare that they have no conflict of interest.

6. Data Accessibility

The *R* script and data to run SDM models as mentioned in our Methods and Materials are available through GitHub; github.com/StevenVB12/SDM_Iguana.

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Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.jnc.2020.125888.

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