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March of the Green Iguana: Non-native Distribution and Predicted Geographic Range of *Iguana iguana* in the Greater Caribbean Region

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Photographs by the senior author except where indicated.

Abstract.—Green Iguanas (*Iguana iguana* L. 1758) have been introduced outside their native range largely through the pet trade. In many places, exotic populations have invaded and many have become established. Of special concern is the Greater Caribbean Basin, where several exotic populations of Green Iguanas have had a negative impact, and may threaten the conservation of several native species, including possible native and distinct forms of *I. iguana* in the Lesser Antilles, and the endangered Lesser Antilles Iguana (*I. delicatissima* Laurenti 1768). We assessed the risk of spread and invasion by Green Iguanas in the Greater Caribbean Basin using the maximum entropy niche-modeling algorithm (MaxEnt) to predict the potential distribution of this reptile. We used a total of 187 location points that represented occurrences from both the native and the invasive range, coupled with environmental data as predictor variables. Our model had average training and test AUC values of 0.90 and 0.87 respectively, indicating a high predictive ability. The model predicts suitable conditions for *I. iguana* in south and central Florida (mainly along the coast), and in regions of all the islands in the Caribbean. Given the known negative impact of Green Iguanas and their dispersal capabilities, governments in the Greater Caribbean Basin should manage non-native populations to prevent further spread, and revise and enact laws that allow management agencies to respond quickly in the case of new Green Iguana incursions.

Keywords: *Iguana iguana*, exotic species, risk assessment, niche modeling, Caribbean Basin.

Introduction

Many animals have been introduced outside their native ranges. In the Greater Caribbean Region, thousands of reptiles and amphibians have been imported as food, through the pet trade, or as hitchhikers on cargo (Powell et al. 2011). A high profile example of this is the Green Iguana (*Iguana iguana* L. 1758). Green Iguanas are large (up to 2 m long), arboreal, herbivorous lizards native to the Neotropics. These reptiles can be found from xeric to mesic habitats, from coastal areas to inland mountain ranges, and in both open and forested areas (Moberly 1968, Müller 1972, Distel and Veazey 1982, van Devender 1982, van Marken Lichtenbelt et al. 1993, Benítez-Malvido et al. 2003). Moreover, they also inhabit and reproduce well in urban areas. With such a wide tolerance to variable conditions, that *I. iguana* is the most widespread iguanine species and perhaps one of the reptiles with the most extensive geographic ranges in the Americas is not surprising.

During the last half-century, Green Iguana populations have suffered heavy losses in their native range through collection and exportation to satisfy the pet trade industry (Fitch et al. 1982, Harris 1982, Muñoz et al. 2003). As a result of the introduction of *I. iguana* outside its native range, some populations became established and even invasive (e.g., in Florida and Puerto Rico; Kraus 2009). We have now begun to see impacts associated with the establishment and spread of *Iguana iguana.*

As with any invasive species, prevention would be the best option to deal with these reptiles, both in economic and logistical terms (Leung et al. 2002, Powell et al. 2011). Considering the negative impact caused by Green Iguanas in their invasive range, assessing the risk of invasion in order to assist in development of sound preventive strategies would be advantageous. In this article, we employ niche-modeling techniques to identify areas likely to be

This Green Iguana has taken up residence at the "Paseo Lineal" in the Central Park of San Juan, Puerto Rico.

vulnerable to invasions of *I. iguana* across the Greater Caribbean Basin.

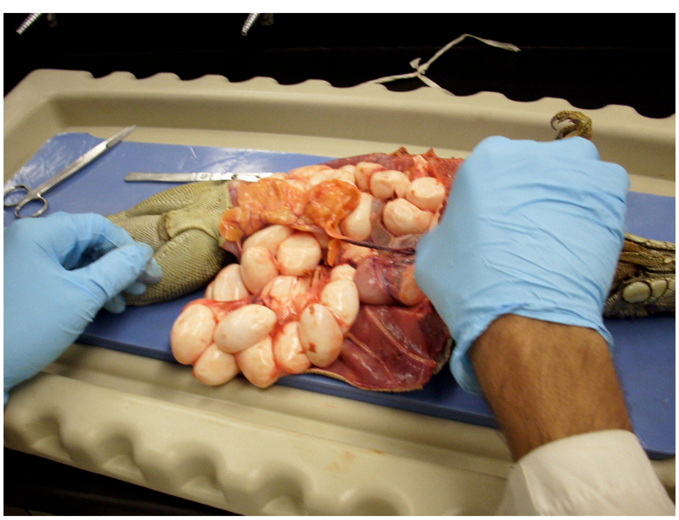
Methods

In order to generate niche models that allowed us to identify areas vulnerable to Green Iguana invasions, we used herpetological specimen occurrence records obtained from data published by Arctos, California Academy of Science, Carnegie Museum of Natural History, Colecciones Instituto Alexander von Humboldt, Comisión Nacional para el conocicmiento y uso de la Biodiversidad (Mexico), Conservation International, Finnish Museum of Natural History, Instituto de Biología Universidad Nacional Autónoma de México, Los Angeles County Museum of Natural History, Museum of Comparative Zoology (Harvard University), Museum of Vertebrate Zoology (University of California), National Museum of Natural History, Staatliches Museum fur Naturkunde Stuttgart (Germany), University of Colorado Museum of Natural History, and Yale University Peabody Museum (accessed through the Global Biodiversity Information Facility Portal, http://data.gbif.org/species/, and the HerpNet2 Portal, http://www.herpnet2.org), along with occurrence records that we collected in Puerto Rico. After scrutinizing each location to remove duplicates from the dataset and to set a minimum distance of 10 km between each point (to prevent overfitting), we had 187 location points including both the native (166) and the invasive (21) ranges. Locations from the invasive range were restricted to jurisdictions inside the calibration area where breeding has been reported: Florida (2) and Puerto Rico (19). Although *I. iguana* has been reported as established and/or invasive in other places within the Caribbean Basin, no precise geo-referenced locations were available to us, so those sites were not included in our analysis.

For predictive variables, we used the Bioclim global climatic layers dataset (WorldClim, http://www.worldclim.org/current). These climatic layers have a resolution of 30 arc-seconds (~1 km^2) and are derived from monthly temperature and rainfall values that include annual trends, seasonality, and extreme or limiting environmental factors calculated from 1950 to 2000 (Hijmans et al. 2005). BIL layers were converted into GRD and ASC layers using DIVA-GIS (http://www.diva-gis.org/) and trimmed to focus on the Neotropics. From the available climatic information, we selected *a priori* the mean, extreme, and seasonality values in temperature and precipitation variables (layers) to represent conditions that are biologically important to and may limit the distribution of Green Iguanas (e.g., Moberly 1968, van Devender 1982, Bock and Rand 1989, van Marken Lichtenbelt et al. 1993, van Marken Lichtenbelt et al. 1997).

To model the realized distribution of *I. iguana*, we used the MaxEnt software, which employs the maximum entropy method for niche modeling (MaxEnt, http://www.cs.princeton.edu/~schapire/maxent/). MaxEnt is a machine learning method that uses presence-only data in combination with predictive variables to model a species' geographic distribution (Phillips and Dudík 2008 and references therein).

To predict the potential for invasion, we constructed a model using the combination of points from the native and invasive ranges (e.g., Steiner 2008). The calibration area, which includes all the climatic information for the occurrence locations of *I. iguana* in our dataset, was defined as the smallest rectangle that encompassed all the location records that we used in the model (longitude -107– -35°, latitude -23– 26°) and does not include information from oceanic areas. For the model, we ran 10 replicates with bootstrapping and randomly selected 80% of the presence records for training and 20% for testing in each run. The model was run without using the Threshold feature (i.e., the Auto and Threshold features were set to off) to correct for overfitting based on the response curves. For the evaluation of the model, we utilized AUC statistics, that is, the Area Under the ROC (Receiver Operating Characteristic) Curve, and reported the average AUC values. This summary statistic provides a single measure of the model's performance by comparing the predicted geographical distribution of the species to the background data (Phillips et al. 2006). The Training AUC indicates how well the resulting predicted distribution matches the locations of the training data and the Test AUC indicates how well the resulting prediction of the geographic distribution matches occurrence sites that were reserved for model testing (points not used to build the model). Since the Test AUC for our model measures model performance outside the model training points, the Test AUC provides a better indication of predictive ability of the model. Models with AUC values >0.90 are considered to have excellent predictive performance, whereas values <0.90 are interpreted as having a good (0.80–0.90) to poor (<0.70) predictive performance (Swets 1988, Manel et al. 2001, Franklin 2009). We ran simulations using the climatic layers selected *a priori* and evaluated the performance of the model by removing individual layers based on the percent contribution of each variable, Jackknife test of variable importance,



A pregnant female Green Iguana killed by dogs in Humacao, Puerto Rico. Of 69 eggs, 55 contained developing embryos.

This male Green Iguana was captured by the senior author in the Piñones State Forest in Loiza, Puerto Rico. Note the wounds inflicted by a large lizard equipped with teeth, claws, and a tail that can be used like a club. Photograph by Noramil Herrera.

Jackknife of test gain, and Jackknife of the AUC, and selected the combination of layers that resulted in the highest mean, training, and test AUC values. These layers included the annual mean temperature (BIO1), isothermality (BIO3), temperature seasonality (BIO4), minimum temperature of the coldest month (BIO6), the mean temperature of the warmest quarter (BIO10), the annual precipitation (BIO12), precipitation seasonality (BIO15), and the precipitation of the warmest quarter (BIO18; for clarifications on the definitions, refer to http://www.worldclim.org/bioclim).

We then projected the selected model to a set of layers focusing on the Neotropics (longitude -126– -34°, latitude -43– 43°) to visualize the predicted distribution of Green Iguanas in the Americas using Diva-GIS (http://www.diva-gis.org/) and the logistic output format from MaxEnt, which estimates the probability of presence of the species in a given grid, with values ranging from 0 to 1 (Phillips and Dudík 2008). This was done after subtracting the "Clamping layer" provided by MaxEnt, which provides information about climatic values in a given pixel of the predictive layers that are outside the climatic conditions of the training data, thus avoiding incorrect predictions (as recommended by S.J. Phillips, May 2008, MaxEnt Google Group). To generate a binary map of presence/absence, we used the average of the logistic threshold value that maximizes the sum of the test sensitivity and the specificity (MTeS+S) as the cutoff point. The sensitivity is the proportion of correctly predicted presence observations, whereas the specificity is the proportion of correctly predicted absences in terms of the fractional area predicted. This threshold criterion minimizes the mean of the error rate for positive and negative observations (Manel et al. 2001, Freeman and Moisen 2008). When compared to other criteria, the Maximum Sensitivity plus Specificity threshold performs comparably or better than other threshold selection methods in providing accurate presence predictions (Jiménez-Valverde and Lobo 2007, Liu et al. 2005, Freeman and Moisen 2008). In the map, we also present the

Although this iguana is reacting defensively toward the photographer, many Green Iguanas become accustomed to humans and often allow a close approach. This individual was basking near the Piñones State Forest in Loiza, Puerto Rico.

pixels within the range of the MTeS+S minus 1 standard deviation (MTeS+S –*s*). This was done to consider the lower level dispersion from the mean threshold value obtained from the 10 replicates, since some combinations of points yielded a lower threshold value for the presence-absence cutoff point.

Results and Discussion

Our model showed a good performance, with AUC values of ≥0.90, which indicates that the combination of occurrence records and predictive variables used to model the distribution of *I. iguana* was adequate. The model yielded an average training and test AUC value of 0.90 (SD < 0.01) and 0.87 (SD = 0.02) respectively, and a Maximum Test Sensitivity plus Specificity threshold value of 0.30 (SD = 0.11). Based on this threshold cutoff point, the omission rate for the training data is 0.19 (SD = 0.10) and 0.20 (SD = 0.09) for the test points.

In terms of the average variable contributions to the model, the minimum temperature of the coldest month (BIO6) had the greatest contribution (21.7%) and was followed by the mean temperature of the warmest quarter (BIO10, 20.4%), precipitation seasonality (BIO15, 16.0%), the precipitation of warmest quarter (BIO18, 15.1%), and temperature seasonality (BIO4, 14.0%). The remainder of the variables had individual average contributions of <10%: isothermality (BIO3, 5.6%), annual precipitation (BIO12, 5.4%), and annual mean temperature (BIO1, 1.9%).

From the presence records, we were able to extract the climatic information, which shows the variable climatic conditions that Green Iguanas experience through their range (Table 1). The mean annual temperature throughout the range of Green Iguanas in our sample was 25.5 °C, the mean maximum temperature of the warmest month was 32.5 °C, and the mean minimum temperature of the coldest month was 18.5 °C. Moreover, the mean annual precipitation according to the presence records of *I. iguana* was 1,754 mm, with a mean precipitation during the wettest month of 305.81 mm and a mean precipitation during the driest month of 33.0 mm.

In general, the predicted distribution of our model within its native region is in agreement with the native distribution of *I. iguana* as described in the literature (Map A). Green Iguanas can be found from Sinaloa, México to Ecuador on the Pacific versant and to northern Paraguay on the Atlantic versant (Etheridge 1982, de Queiroz 1995, Lever 2003, Townsend et al. 2003). Some patchiness in terms of suitable distribution areas is evident. For example,

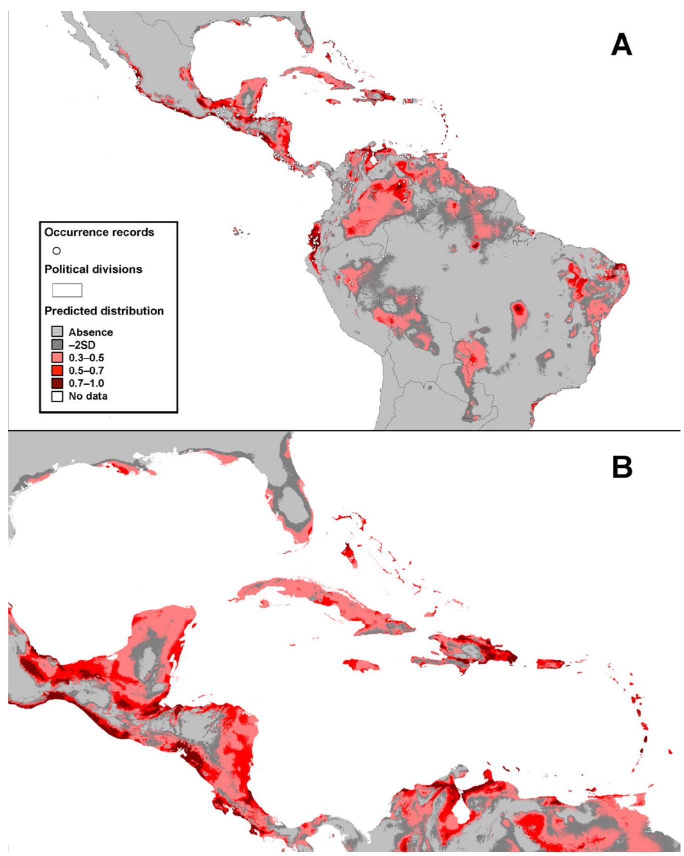
Table 1. Climatic conditions experienced by *Iguana iguana* throughout its range from 187 presence records and climatic variables from Bioclim. Means are presented ± one SD (range in parentheses).

Variable	Mean
Mean annual temperature	25.50 ± 2.91 °C (18.20–28.30 °C)
Maximum temperature of warmest month	32.50 ± 1.97 °C (23.30–37.30 °C)
Minimum temperature of coldest month	18.50 ± 2.78 °C (9.70–23.70 °C)
Annual precipitation	1,754.03 ± 882.35 mm (234.00–4,900.00 mm)
Precipitation of wettest month	305.81 ± 139.11 mm (68.00–759.00 mm)
Precipitation of driest month	33.70 ± 37.32 mm (0.00–190.00 mm)

some habitat suitability gaps occur from the border of Costa Rica and Panama to suitable areas in Colombia. This could be due to the small sample size that we have for Panama in our dataset (only two records). However, the locations of studies done on Green Iguanas in Panama coincide with the predicted areas. This also is observed in parts of South America. One factor that could explain the patchiness of suitable habitat despite the ample distribution of Green Iguanas could be sampling problems. Our data set might not represent all the possible conditions in which Green Iguanas could be present. Assuming that the predictions are correct, the connectivity of climatically suitable areas through rivers and waterways might explain the patchy distribution of suitable habitats. Green Iguanas are commonly found along riverbanks both in their native and invasive ranges, and in Florida and Puerto Rico, they seem to use waterways to disperse (Rivero 1998, Meshaka et al. 2004, Joglar 2005). Although some of the occurrence points fall out of the areas predicted with suitable climate as expected by the omission rates for the selected threshold, the occurrence locations fall within or close to rivers connected to suitable areas (not shown).

Green Iguanas also are considered native to several islands of the Greater Caribbean Basin including Bonaire, Klein Bonaire, Aruba, Trinidad, Tobago, Grenada, the Grenadines, Saint Vincent, Saint Lucia, and Montserrat (Lazell 1973, Etheridge 1982, Powell 2004). A phylogenetic analysis of the relationships between *I. iguana* lineages suggests at least three radiation events into Curaçao, Saint Lucia, and into Saba and Montserrat (Malone and Davis 2004). All of these locations show climatic suitability for Green Iguanas according to our model. The status of other populations in the Lesser Antilles has been disputed as to whether they should be considered native or introduced (Censky and Kaiser 1999, Thomas 1999, Powell 2004, Powell and Henderson 2005, Platenberg and Boulon 2006, Platenberg 2007, Stahl 2009). Our model predicts climatic suitability for Green Iguanas in all of the Caribbean Islands and southeastern Florida (Map B). Most of the islands had probabilities >0.60. The threshold criterion that maximizes the sum of the sensitivity and the specificity has been regarded as a somewhat conservative threshold for species with widespread ranges (Manel et al. 2001, Freeman and Moisen 2008). Given that the purpose of this model is invasion risk assessment and that the selected threshold may under-predict the distribution of widespread species, the fact that most of the jurisdictions within the Greater Caribbean Basin are predicted as suitable for Green Iguanas is worrisome. The predictions for the Greater Caribbean Basin are maintained whether we use all the occurrence points or just data from the native range to train the model (analyses not shown).

On the Puerto Rican Bank, our model predicts highly suitable areas, especially along the coasts. The U.S. Virgin Islands is one of

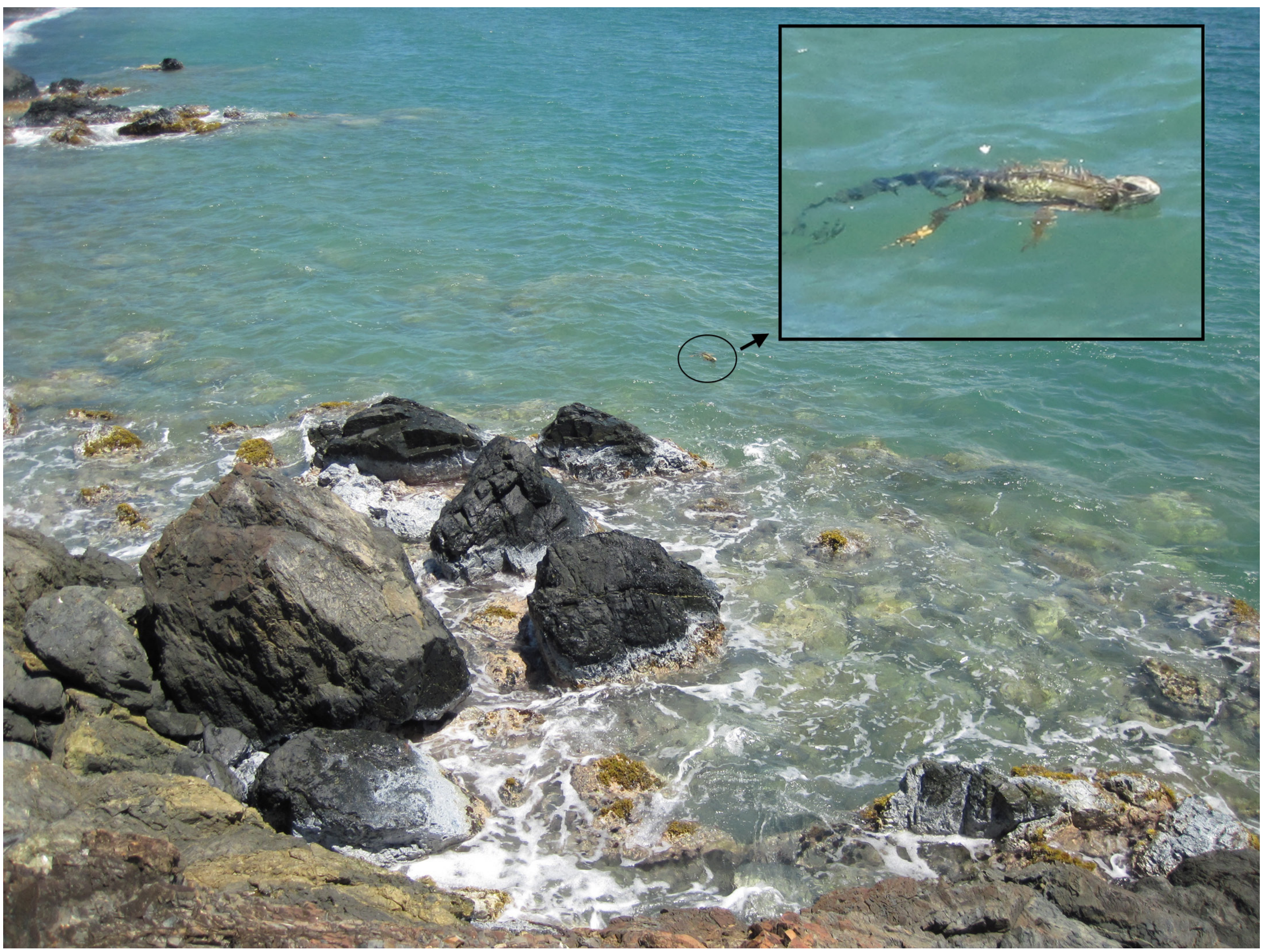


Map. Predicted distribution for *Iguana iguana* in the Americas (A) and the Greater Caribbean Basin (B). Gray represents absence according to the threshold value that maximizes the sum of the training specificity and the sensitivity (MTeS+S; <0.30), and dark gray represent the MTeS+S – 1*s*. Presence probabilities are represented in shades of red, with increasing probabilities denoted by darker color.

the places where the status of *I. iguana* is uncertain, and present populations (which are located on the main islands) might be the result of introductions through the pet trade (Powell 2004, Platenberg and Boulon 2006, Platenberg 2007). In Puerto Rico, *I. iguana* also has been introduced through the pet trade and is considered highly invasive (Rivero 1998, Thomas 1999, López-Torres 2011). On the island, the negative impact caused by iguanas is now beginning to become apparent. These reptiles are known to interrupt air traffic in the Luis Muñoz Marín International Airport (SJU) when they enter the runways to bask (Engeman et al. 2005). Currently, the FAA and the PR Ports Administration spend $98,000 annually to prevent intrusions of iguanas onto the runways and to eliminate nests on airport premises (B. Vázquez, pers. comm.). They also damage gardens and ornamental plants (Carlo-Joglar and García-Quijano 2008) and even have caused $13,000 worth of damage to the gardens of the San Juan State Court (Joel Ortiz, *El Nuevo Día* 27.IV.2012). They have also severely damaged red and black mangrove forests (*Rhizophora mangle* and *Avicennia germinans* respectively), sometimes resulting in tree mortality (J. Gómez-Carrasquillo et al., unpubl. data; Carlo-Joglar and García-Quijano 2008).

Recently, a 1–2 year-old Green Iguana reached the Mona Island Nature Reserve on board the boat that goes to the island from Mayagüez (PR) to collect trash (K. Barrientos, pers. commun.). Luckily, when the boat reached the pier, the crew noticed the iguana and alerted biologists and DNER personnel on the island. The iguana was eventually captured and euthanized. The Mona Island Nature Reserve is home to the endangered endemic Mona Ground Iguana (*Cyclura stejnegeri*).

Green Iguanas were initially sold as pets in the Dominican Republic in the early 1990s (Pasachnik et al. 2012). In that study, Pasachnik et al. (2012) identified twelve general locations where the presence of Green Iguanas has been confirmed by either observations or interviews in the local communities. All of these locations fall within the areas predicted by the model as suitable for Green Iguanas. Due to the negative impacts associated with the invasion of Green Iguanas, the Dominican Ministry of the Environment



Green Iguanas are excellent swimmers and are known to have colonized islands after swimming or rafting considerable distances. Censky et al. (1998) recorded Green Iguanas reaching Anguilla on rafts of floating vegetation that had drifted about 320 km from their source in Guadeloupe. This individual was photographed at Roosevelt Roads, a former naval station in Ceiba, Puerto Rico.

This imposing individual greeted tourists near the Cruise Terminal in Charlotte Amalie, St. Thomas, U.S. Virgin Islands.

implemented a resolution in 2010 that prohibits the importation and commercialization of these reptiles (Pasachnik et al. 2012).

The introduction of Green Iguanas of continental origin to some of the Lesser Antilles has resulted in mixed populations of presumably native *I. iguana* and their continental relatives, and the co-occurrence of the introduced iguanas with the endemic and endangered Lesser Antillean Iguana (*I. delicatissima*; e.g., Daltry 2009, Morton and Krauss 2011). Introduced *I. iguana* (of continental origin) has been shown to compete and displace *I. delicatissima* in the islands where they co-occur and the two species hybridize, which has jeopardized conservation efforts for the Lesser Antillean Iguana (Day and Thorpe 1996, Breuil 1997, Powell and Henderson 2005, Knapp 2007, Breuil et al. 2010). This raises concerns because some of these native Green Iguanas in the Lesser Antilles may warrant recognition as distinct populations (or even species; Malone and Davis 2004, Powell 2004), and interbreeding with introduced continental iguanas might alter the gene pool and break up adaptive gene complexes. In Saint Lucia, where a potentially distinct form of *I. iguana* is endemic, continental iguanas were introduced through the pet trade and are a cause of conservation concern (Morton and Krauss 2011).

Iguana iguana was also introduced through the pet trade to Barbuda and Saint Martin (Powell 2005). It has also been introduced illegally into the UK Overseas territories of the British Virgin Islands, the Cayman Islands, and Turks and Caicos Islands (Seidel and Franz 1994, Edgar 2010, Reynolds and Niemiller 2010). On Grand Cayman, Green Iguanas are spreading eastward across the island with an exponentially growing population (interview with Frederick Burton by Tammi Sulliman, *Cayman 27 News*, 21.IV.2009). They are considered a nuisance, are now causing a variety of problems, and might pose a threat to the native critically endangered Rock Iguana (*Cyclura lewisi*; Seidel and Franz 1994, Burton 2007, Edgar 2010).

On Anguilla, one population of Green Iguanas is almost certainly descended from introduced pets, and another originated from Guadeloupe after a hurricane in 1995 sent at least 15 iguanas rafting on trees until they reached the Anguillan coast some 200 miles away (Censky et al. 1998; Hodge et al. 2003, 2011). According to Breuil (2002), Green Iguanas found on Les Îles des Saintes, Basse-Terre, Grande-Terre, and Martinique should also be considered invasive. All of these islands have high probabilities of predicted distribution for Green Iguanas, so based on the climatic variables included in the analysis, populations are expected to continue spreading.

In the U.S., these reptiles have been imported primarily from El Salvador and Colombia (Hoover 1998), and are now considered invasive in Florida (Townsend et al. 2003, Krysko et al. 2007), where they are known to cause extensive damage to gardens and ornamental plants (Kern 2004, Krysko et al. 2007) and might aid in the dispersal of invasive species of plants (Meshaka et al. 2007, Sementelli et al. 2008). The consumption of *Drymaeus multilineatus*, a native tree snail, and interactions with the Florida Burrowing Owl (*Athene cunicularia floridana*; a species of special concern) elevates concerns about the possible negative ecological impact that this species might have (McKie et al. 2005, Townsend et al. 2005). Moreover, these lizards are considered an erosion hazard in the state due to their burrow construction habits. Some areas in Florida have more than 2,000 burrows/ha, which could result in high costs due to erosion-related damages and repairs (Sementelli et al. 2008). The predictions of our model agree with the areas presently occupied by Green Iguanas in the state (Meshaka et al. 2004, Krysko et al. 2007; Florida Museum of Natural History Herpetology Database). Suitable predicted areas also occur along the coast in Titusville and Merritt Island, and in the Tampa Bay area, but with probabilities <0.40 (except for the dark spots in the St. Petersburg area; see Map B). Farther north along the Atlantic Coast, the model also predicts suitable areas east of Jacksonville north to Brunswick (Georgia), and from west of Live Oak to Pensacola along the Gulf Coast. Again, the majority of the predicted areas have probabilities <0.40, with higher probabilities in coastal areas (Map B). The cold temperatures in northern latitudes likely limit the distribution of *I. iguana* in the U.S. (Townsend et al. 2003, Krysko et al. 2007). According to our model, suitable climatic conditions for Green Iguanas are limited to <31° latitude along the coasts. From our Green Iguana occurrence data, the sample average for the temperature in the coldest month (BIO6) is 18.38 °C (~65 °F; Table 1), and in Florida, *I. iguana* populations were adversely affected for a short period of time when temperatures dropped below 10 °C (50 °F; Krysko et al. 2007). The annual mean temperature range is 19–20 °C in northern parts of Florida predicted as suitable, and the mean temperature of the coldest month goes down to 4–5 °C according to our climatic layers. Green Iguanas are unlikely to survive prolonged periods (>1 month) of cold temperatures (<18 °C) without behavioral modifications (e.g., seeking shelter in burrows or water; Townsend et al. 2003). Also, a population of Green Iguanas has been reported in the Rio Grande Valley of Texas (Meshaka et al. 2004), but our model does not predict suitable areas there (probabilities <0.01). Currently, the fate of this feral population is uncertain, and no recent accounts report established Green Iguanas in Texas, although occasional escaped pets and Spiny-tailed Iguanas in the genus *Ctenosaura* are known to occur (A. Gluesenkamp, pers. comm.).

Based on the high dispersal capabilities of *I. iguana* and the suitability of climatic conditions in the Greater Caribbean Basin, Green Iguanas clearly have a high potential for invasion. Virtually all Caribbean Islands currently unoccupied by Green Iguanas are vulnerable to new invasions, especially in coastal areas, based on the climatic suitability. These lizards also have the potential to spread from places where non-native Green Iguanas have become established and currently remain localized. The same is true for many islands in the Pacific. This model was projected into the Pacific Region, where established populations of Green Iguanas have also been reported. Suitable climatic conditions for the establishment and spread of Green Iguanas are abundant (Falcón et al., in press).

That our model was developed using global environmental layers, in which considerable data are based on extrapolation, is important to mention (Hijmans et al. 2005). This limits the predictability of Green Iguana distribution especially at finer scales (e.g., Christenhusz and Toivonen 2008). Moreover, other important factors might affect local distributions of Green Iguanas for which we do not have information at a global scale. To address local-scale distribution of Green Iguanas (e.g., in Puerto Rico), one should use variables (layers) obtained at a finer scale. In the case of Florida and Puerto Rico, Gap Analysis Projects (Pearlstine et al. 2002, Gould et al. 2008) provided those local scale data, which included land cover and stewardship, vertebrate occurrence, and other natural history information. These data are collected in a standardized way as part of the U.S. National Gap Analysis Program (Scott et al. 1987, Scott and Jennings 1994), which makes comparable analyses between jurisdictions in the U.S. The problem with such data is that coverage is limited, especially for tropical regions, making broad-scale species distribution modeling such as that which we present here dependent on global datasets.

Currently the possession and importation of Green Iguanas is regulated depending on the jurisdiction where they have been

Stuffed iguanas for sale in the gift shop of El Portal Visitor Center at El Yunque National Forest. Although not native and highly invasive, because of their visibility, Green Iguanas have come to represent wildlife for many tourists visiting Puerto Rico.

introduced. Releasing iguanas into the wild is illegal even where possession is allowed (e.g., Florida and Puerto Rico). In Florida, Sementelli et al. (2008) suggested a ban on the possession of these reptiles due to the evident negative impact. In Puerto Rico, people are allowed to possess, hunt, and export iguanas as long as they are not returned to the wild. However, the importation of this species into Puerto Rico has been illegal since 2004, when they were declared a nuisance invasive species under the regulations of the Department of Natural and Environmental Resources. The case of the Grand Cayman Islands is curious in the sense that *I. iguana* is invasive and causes similar problems as in Puerto Rico and Florida, but because of the general protection offered to iguanas by the Conservation Law (Animal Law 2003 Revision) intended to safeguard the endemic Grand Cayman Blue Iguana (*Cyclura lewisi*) and Sister Isles Rock Iguana (*Cyclura nubila caymanensis*), they actually enjoyed protection until the law was finally amended in 2010.

Not everything is negative when Green Iguanas become established outside their native range. In Florida and Puerto Rico, some people enjoy having iguanas around, and tourists are often drawn to these reptiles (Meshaka et al. 2004, García-Quijano et al. 2011). The tourism industry has taken advantage of this and uses Green Iguanas in advertisements, on apparel, and as attractions for nature excursions — and shops even sell figures and stuffed iguanas. The trade in iguanas as pets has generated enormous profits in the U.S. (Hoover 1998), and in Florida, local pet stores were supplied from local populations after the establishment of Green Iguanas in the state. Moreover, in Puerto Rico, "Best Iguana Puerto Rico Meat Export" is seeking permits to not only supply local restaurants with Green Iguana meat from individuals captured in the wild, but also to export it to the U.S. (Inter News Services, *El Nuevo Día*, 07.II.2012; E. Lloréns Vélez, *Caribbean Business*, 08.II.2012). The potential benefits of introduced Green Iguana populations have yet to be analyzed critically and carefully to make sure that *I. iguana* does not pose a threat to local fauna and flora and is not likely to cause negative environmental or economic impacts.

Powell et al. (2005) suggested that introduced reptiles and amphibians in the Greater Caribbean have a 70% success rate for establishing new populations. If unimpeded, *I. iguana* is likely to

Green Iguanas are invasive in Puerto Rico, and sufficiently abundant in some areas that their burrows threaten the integrity of paved roads, sidewalks, and verandas. This burrow was along the state road along the coast near Dorado, Puerto Rico.

spread throughout the Caribbean Basin as it has shown to be adept at both natural and human-assisted dispersal. Countries in the Caribbean Basin that do not have regulations on the importation, possession, and release of Green Iguanas should consider laws and regulations enacted by the jurisdictions mentioned above in order to prevent human-mediated dispersal. We concur with the recommendations by Sementelli et al. (2008) that prohibit private ownership of Green Iguanas in places where they have the potential to cause or are causing a negative impact. Allowing the private possession of these reptiles in places that are suitable for their occurrence can aid the establishment and spread of populations, as individuals escape from captivity or are intentionally released by their owners. Where non-native populations of *I. iguana* occur and the possibility of negative impact exists, control and/or eradication measures should be implemented immediately. Local governments should also be aware of the possibility of natural dispersal from islands that have already been invaded (e.g., Censky et al. 1998) and plan accordingly in order to prevent the establishment of new iguana populations. Control of the Green Iguana invasion might best be undertaken by using a regional approach that encompasses the Greater Caribbean (e.g., Powell et al. 2011). Otherwise, the march of the Green Iguanas will continue and the negative genetic, ecological, environmental, and economic effects currently associated with these beasts could soon affect the remainder of the region.

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