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## EFFICIENT NOCTURNAL CAPTURE METHODS FOR CONTROLLING A DIURNAL AND ARBOREAL INVASIVE LIZARD SPECIES

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**Abstract.**—We describe effective methods for capturing and removing large quantities of invasive Green Iguanas (*Iguana iguana*) in both The Bahamas and southern Florida, USA. We used methods typically just after dusk that lasted 5 h. We used head lamps or hand-held flashlights to spot iguanas before capturing them by hand, or with snake tongs, a telescoping pole, or quadcopter drone to knock off iguanas from their arboreal perches and then catching them with a net below. At times we conducted daytime removals using a live trap or snare placed at active burrow entrances. In The Bahamas, from 2 December 2014 to 10 August 2020, we conducted 81 surveys for a total of 1,215 person-hours of fieldwork and removed 18,121 Green Iguanas. In Florida, from 25 April 2018 to 19 May 2020, we conducted 158 surveys for a total of 2,370 person-hours of fieldwork and removed 4,557 Green Iguanas. Our effective methods resulted in the most (22,678) invasive Green Iguanas removed from any known study without the aid of firearms and can be used as a tool for rapid response to new introductions of Green Iguanas around the world, as a management tool in already infested areas, and as an efficient capture method for researchers working with this or perhaps other arboreal, diurnal lizard taxa.

**Key Words.**—collecting; Green Iguana; Florida; *Iguana iguana*; introduced species; management; removal; The Bahamas

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### INTRODUCTION

Green Iguanas (*Iguana iguana*) are native to low elevations from southern Mexico to northern South America, as well as many Caribbean islands (Bock et al. 2018; Breuil et al. 2019). This species has been introduced and populations have become established in at least 19 countries with tropical and subtropical islands being the most vulnerable (International Union for Conservation of Nature [IUCN] 2017), especially in Fiji, the Canary Islands, The Bahamas, Grand Cayman, and the USA in Puerto Rico and Florida. Green Iguanas have adapted extremely well to areas where they have been introduced and been documented causing considerable negative effects on the environment, economy, and human health. Green Iguanas create burrows that short-circuit power lines and undermine roadways, sidewalks, seawalls, and other manmade structures, at times causing erosion and collapse (Krysko et al. 2007, 2019; IUCN 2017). Because of this, they are defined as an invasive species (Invasive Species Advisory Committee. 2006. Executive Order 13112, Invasive Species Definition Clarification and Guidance White Paper, Submitted by the Definitions Subcommittee of the Invasive Species Advisory Committee (ISAC). Available from [https://www.doi.gov/sites/doi.gov/files/uploads/isac\\_definitions\\_white\\_paper\\_rev.pdf](https://www.doi.gov/sites/doi.gov/files/uploads/isac_definitions_white_paper_rev.pdf) [Accessed 1 July 2021]; Kraus 2009; Meshaka 2011; Thomas et al. 2013).

In Florida and Puerto Rico, Green Iguanas have become a major nuisance by eating protected Red Mangroves (*Rhizophora mangle*), Papaya (*Carica papaya*) saplings, landscape plants, orchids, and fruit, and creating unsanitary and unsightly conditions by defecating on swimming pool decks, docks, and vehicles (Kern 2004; Krysko et al. 2007, 2019; De Jesús Villanueva 2017). Green Iguanas may transmit *Salmonella* to humans and act as seed dispersers for invasive plant species and have been implicated in the extirpation of the federally listed as Endangered Miami Blue Butterfly (*Hemiargus thomasi bethunebakeri*) on Bahia Honda Key (Krysko et al. 2007). Additionally, Iguana Crossing signs were posted on Key Biscayne to advise motorists of the potential driving hazard there (Krysko et al. 2007), and the sight of these large exotic lizards basking and foraging in the grass along the Overseas Highway in the Keys constantly slows down vehicular traffic and raises concern for causing accidents (Krysko et al. 2007). Furthermore, Green Iguanas are considered an airstrike and flight hazard by the Federal Aviation Administration (FAA) in The Bahamas, Puerto Rico, and Florida due to their basking on and burrowing under runways (Engeman et al. 2005; IUCN 2017). Invasive Green Iguanas have been implicated in hybridizing with the native Lesser Antillean Iguana (*Iguana delicatissima*) in the Lesser Antilles (Vuillaume et al. 2015) and Sister Isles Iguana (*Cyclura caymanensis*) on Little Cayman (Moss et al. 2018). Thus,

policy makers have been urged to proactively advance manifold strategies to reduce the impact of invasive Green Iguanas including implementing well-coordinated and resourced plans to humanely remove or control invasive iguanas (Knapp et al. 2021).

Capturing and removing invasive species such as Green Iguanas from the wild can be difficult because of their large size (up to 58 cm snout-vent length [SVL]) and elusive behavior (Krysko et al. 2019). They are extremely wary and quick, and usually bask during the daytime and sleep at night in trees, especially in those that overhang water, where they can dive to escape capture (Krysko et al. 2007, 2019). Capture methods have included using: (1) spot lights at night to locate sleeping hatchlings and then using a hook to lower branches within reach to grab iguanas by hand (Burghardt and Rand 1985); (2) snare traps (Kern 2004) and live traps (e.g., Havahart traps, Woodstream Corporation, Lancaster, Pennsylvania, USA; Tomahawk traps, Tomahawk Live Trap LLC, Hazelhurst, Wisconsin, USA) baited with flowers or fruit; (3) nooses with a long pole while iguanas are basking or sluggish because of unusually cold weather during the day or while they are sleeping at night (Krysko et al. 2007); (4) boats to noose iguanas from trees, sometimes stretching out nets to catch individuals jumping from trees to the water below (also see Hamilton et al. 2007); (5) constructing artificial nesting sites to remove their eggs before hatching (Werner and Miller 1984; Krysko et al. 2007); and (6) snares and firearms (Rivera-Milán and Haakonsson 2020). Although the methods above are proven successful, except for firearms, individually they are not efficient to remove most or all Green Iguanas from a particular area. Herein, we demonstrate an example of invasive species management in practice by describing our methods that have been highly effective at capturing and removing large quantities of invasive Green Iguanas in both southern Florida and The Bahamas. Our approach consists of modifying some methods described above and using novel techniques.

#### MATERIALS AND METHODS

**Study sites.**—In The Bahamas, from 2 December 2014 to 10 August 2020, we collected iguanas on North Cat Cay (25.5516°N, 79.2793°W). This site is a private 12 ha island 13.6 km south of Bimini, The Bahamas. In Florida, USA, from 25 April 2018 to 19 May 2020, we collected iguanas in the Florida Keys, Monroe County, at five state parks: (1) Bahia Honda (24.6593°N, 81.2756°W; 212 ha); (2) Curry Hammock (24.7421°N, 80.9823°W; 404 ha); (3) Dagny Johnson Key Largo Hammock Botanical (25.1755°N, 80.3676°W; 980 ha); (4) John Pennekamp Coral Reef (25.1255°N, 80.4066°W; 1,173 ha); and (5) Windley Key Fossil Reef Geological State Park (24.9501°N, 80.5956°W; 14 ha).

**Collection effort and techniques.**—Our methods were the same for both removal studies. We first conducted daytime surveys at the beginning of projects, or in new areas, to determine locations and concentrations of active Green Iguanas, followed by once each month to monitor population trends. We used a three-person team to conduct between 1–10 field days of nighttime surveys/collections each month, depending on the Green Iguana population size. Our general methods include surveys and collections beginning just after dusk and ending 5 h later to remain inconspicuous so as to not concern the public, and this is the most effective way to capture Green Iguanas when they are sleeping in trees. One team member surveyed areas consisting of low vegetation using a heavy-duty light emitting diode (LED) Fenix HP15UE head lamp (Fenixlight Ltd, Shenzhen City, Guangdong Province, China) or an Anker LC130 handheld flashlight (Anker Innovations Technology Company Ltd, Shenzhen City, Guangdong Province, China) to initially spot an iguana and then capture it by hand, or with Pillstrom snake tongs (Pillstrom Tongs LLC, Rogers, Arkansas, USA). We sometimes used a 1.3–3.6 m [4.5–12 ft] telescoping boat hook (Model #289498; West Marine, Watsonville, California, USA) as an aide to gently lower the tree branch to a close proximity for successful capture. Simultaneously, the other two team members surveyed areas with taller vegetation using a head lamp and they captured iguanas using a 2.4–4.8 m (8–16 ft) Wooster Sherlock (The Wooster Brush Company, Wooster, Ohio, USA) or Mr. LongArm Pro-Lok 2.4–7 m (8–23 ft) telescoping painter's pole (Mr. LongArm Inc., Greenwood, Missouri, USA). When an iguana was located, one person extended the pole to the appropriate length and knocked the lizard off its arboreal perch while it was sleeping. The other team member then attempted to catch the lizard either by hand, or more effectively using a landing net used by fisherman before the lizard hit the ground (Fig. 1). If the iguana evaded capture by hand or net, it was easily apprehended because it was recently sleeping and not very active as it typically would be during the daytime. For iguanas that were too high to reach with a telescoping pole, we employed a novel technique consisting of using a remote-controlled DJI Mavic Air2 quadcopter drone (Da-Jiang Innovations Science & Technology Company Ltd, Shenzhen City, Guangdong Province, China) to physically knock down the lizard into our net below. Although most of our collection efforts took place at night, at times we conducted daytime removals by using a Hti@XT Portable Video Borescope scope (Dongguan Xintai Instrument Company Ltd, Dongguan City, Guangdong Province, China) to verify an active iguana burrow and then deploying a 61 × 12.7 × 12.7 cm Tomahawk S50 repeating live trap or Thompson 1S-40 and 00S-20 snare (Thompson Snares LLC, Hortense, Georgia, USA) at the burrow entrance.



**FIGURE 1.** Two team members working together at capturing an adult invasive Green Iguana (*Iguana iguana*) in tall vegetation on Cat Cay, The Bahamas, 26 October 2019. Note that one person is using an extended painter's pole to knock the lizard off its arboreal perch while it is sleeping, while the other person catches the lizard using a fisherman's landing net below. (Photographed by Joseph A. Wasilewski).

Green Iguanas were humanely euthanized using a Blitz-Kerner Stunner Kit (turbocut Jopp GmbH, Bad Neustadt, Germany) and pithing following the American Veterinary Medical Association (AVMA) Guidelines for the Euthanasia of Animals (<https://www.avma.org/sites/default/files/2020-01/2020-Euthanasia-Final-1-17-20.pdf>; ver. 2020.0.1).

## RESULTS

We successfully removed 22,678 Green Iguanas from these two project sites (Fig. 2). In The Bahamas, we conducted 81 surveys on North Cat Cay (25 d/mo), each consisting of 5-h days (three team members) for a total of 1,215 man-hours of fieldwork. We removed



**FIGURE 2.** The successful removal in one evening of 461 invasive Green Iguanas (*Iguana iguana*) on Cat Cay, The Bahamas, 12 August 2016. (Photographed by Joseph A. Wasilewski).



FIGURE 3. Twenty gravid female invasive Green Iguanas (*Iguana iguana*) with developing oviducal eggs removed on Cat Cay, The Bahamas, 26 January 2018. (Photographed by Joseph A. Wasilewski).

18,121 Green Iguanas (mean #iguana/man-hour =  $14.9 \pm 0.002$  [standard error]), with an additional 502 eggs from 27 gravid females (Fig. 3; mean #eggs/female =  $18.6 \pm 1.625$ ; range, 5–39). We also removed another 86 gravid females but did not count all developing oviducal eggs because our primary objective was large-scale eradication. In Florida, we conducted 158 surveys at each of the five state parks: 17 at Bahia Honda; 31 at Curry Hammock; 40 at Dagny Johnson Key Largo Hammock Botanical; 41 at John Pennekamp Coral Reef; and 29 at Windley Key Fossil Reef Geological. Each survey consisted of 5-h days (three team members) for a total of 2,370 man-hours of fieldwork. We removed 4,557 Green Iguanas (mean #iguana/hour =  $1.9 \pm 0.020$ ) with an additional 1,095 eggs from 42 gravid females (mean #eggs/female =  $26.1 \pm 1.535$ ; range, 10–46).

#### DISCUSSION

Introductions of nonnative species have become a worldwide problem and are difficult to prevent and manage, or ultimately eradicate once species reproduce and establish themselves (Simberloff et al. 1997; Kraus 2009; Krysko et al. 2011; Knapp et al. 2021). Our intent herein was to describe and share our highly effective methods of removing large quantities of invasive Green Iguanas after establishment as an example of invasive species management in practice. These techniques can be used as a strategy for rapid response to new introductions of Green Iguanas around the world, as a management tool in already infested areas, and as efficient capture methods for researchers working with this or possibly for other arboreal diurnal lizard taxa.

There are numerous advantages to using the methods outlined in our study. Our methods are simple to follow, inexpensive as necessary equipment is typically available, eliminate the time-consuming need to set and check traps on consecutive daily visits to study sites, and do not require equipment to be left in the field that may be subject to theft or vandalism. Because animal removal can be controversial among members of the public, our methods were conducted after dark, allowing us to remain inconspicuous. We have experienced a high rate of success at removing large quantities (22,678) of invasive Green Iguanas from two countries and different habitats, especially in areas with little to no understory. Additionally, there are only a few minutes of handling and restraint time, which reduces stress on captured animals; and zero nontarget captures or mortality. The only other known study that has removed more Green Iguanas (874,252) than ours occurred on Grand Cayman Island (about 19,684 ha) between October 2018 and August 2019 (Rivera-Milán and Haakonsson 2020), however, they used firearms to directly kill the lizards. Although nonnative reptiles such as Green Iguanas are not afforded legal protection in Florida and removal is encouraged with landowner permission by the Florida Fish and Wildlife Conservation Commission (FWC), animal cruelty laws are still in affect and discharging firearms is a prohibited tactic (Executive Order 20-17 under Florida Administrative Code [F.A.C.] 68-1.009 and 68A-14.001), especially in or near residential neighborhoods where Green Iguanas are commonly observed in high densities. Thus, other humane euthanasia options must be considered (e.g., penetrating captive bolt or blunt force trauma followed by pithing).

The main limitations of our methods were the variable ability of an observer to see Green Iguanas in vegetation and their capturing skills. Similar to other fecund invasive species, our data suggest that eliminating invasive Green Iguanas from a particular area will require the removal of all individuals, as one female can quickly repopulate an area with only a single reproductive event (Krysko et al. 2012). Additionally, continuous removal efforts must be conducted in areas where iguanas can migrate into study sites from adjacent areas. Nonetheless, our approach has proven highly effective at capturing and removing this invasive species in two areas and is likely suitable in other invaded areas and might be effective as well for a variety of similarly sized arboreal lizards. Our paper illustrates invasive species management in practice and provides details on advancing the management of invasive Green Iguanas.

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