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THE JAMAICAN IGUANA (*CYCLURA COLLEI*): A REPORT ON 25 YEARS OF CONSERVATION EFFORT

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Abstract.—**Considered extinct by the late 1940s, the Jamaican Iguana (*Cyclura collei*) was re-discovered in 1970, and its existence confirmed in 1990. The 1970 re-discovery went largely unnoticed; in contrast, the 1990 "re-discovery" spawned a successful international recovery effort. Here we summarize results of that 25-year *C. collei* recovery effort. We also assess the project's achievement of overall objectives, and offer some recommendations for ensuring the long-term persistence of the species.**

Early interventions such as protecting nesting sites and collecting hatchlings for captive breeding and headstarting likely averted the extinction of *C. collei*. Subsequent conservation activities have focused on recovering the remnant population, securing protection for the Hellshire Hills, and establishing a re-introduced population on the Goat Islands. Biological interventions such as nest site protection and headstarting have been demonstrably effective. Most notably, the number of nesting iguanas in the core population increased at least six-fold between 1991 and 2013.

Unfortunately, habitat protection initiatives have met with far less success. Illegal tree cutting for charcoal production continues to degrade Hellshire's remnant forest, and enforcement of existing laws remains an elusive goal. Despite the declaration of the Portland Bight Protected Area (PBPA) in 1999, inclusive of the iguana's entire Hellshire Hills refuge and both Goat Islands, the area continues to be considered for large-scale development projects promoted by the government. A recent (2013) plan to develop a large Chinese-funded port facility and industrial complex in the PBPA is the most worrisome proposal yet presented, and would cripple the iguana's prospects for future survival.

Key Words.—headstarting; invasive species control; reintroduction; re-discovered species; reptile conservation; Rock Iguana

INTRODUCTION

Historical perspective: 1600s to 1990.—The endemic Jamaican Iguana (*Cyclura collei*) was once common along the coastal plains and hills of southern Jamaica (Sloane 1725), but was considered rare or absent on the mainland near the end of the 1800s, presumably due to a combination of over-harvesting, habitat loss, and the introduction of non-native mammalian predators such as the Indian Mongoose (*Herpestes javanicus* [=*auropunctatus*]) (Woodley 1971, 1980; Vogel et al. 1996; Grant et al. 2013). The iguana was considered extinct after a small population disappeared around 1948 from Great Goat Island, located off the western side of the Hellshire peninsula, apparently due to the introduction of the mongoose from the mainland in the mid-1920s (Lewis 1944; Woodley 1980). The species was re-discovered in the Hellshire Hills in 1970 (Woodley 1971, 1980), and again in 1990 (Alberts 1993; Vogel et al. 1996). Those re-discoveries represented the only records of the species on the mainland of Jamaica in the 20th century.

The 1970 re-discovery, the retrieval of a specimen killed by a pig hunter's dog, went largely unnoticed by local and international scientific and conservation communities. This was perhaps unsurprising. Locally, Jamaica lacked a resident herpetologist, and lizards are generally loathed by most Jamaicans. Furthermore, no environmental lobby or environmental NGO existed at the time in Jamaica, and efforts to combat the "global extinction crisis" were in their infancy. For example, the world's large zoos were only beginning to develop support for *in situ* conservation efforts, and the field of conservation biology did not yet exist. So, in the early 1970s, financial and institutional support from a global conservation community – so critical in most species recovery efforts today – was simply not available to take up the iguana's cause.

A second chance: 1990–2014.—In contrast to the quiet and largely ignored 1970 re-discovery, the 1990 re-discovery generated enormous local and international interest, and galvanized a successful recovery effort that continues today (Alberts 2000; Vogel et al. 1996; Wilson 2011). The 1990

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re-discovery was different for two reasons. First, Jamaica had a resident herpetologist at the time, in the late Dr. Peter Vogel, then a Lecturer in the Department of Life Sciences, at The University of the West Indies, Mona (UWI). Second, the period 1970–1990 witnessed an international awakening to the global extinction crisis, formalized by the genesis of a new discipline, conservation biology (Soulé 1986). These developments led to a myriad of new funding opportunities, conservation positions, and diverse institutions eager to engage in conservation research and recovery efforts. Notably, the world's universities and major zoos began supporting conservation efforts aimed at averting extinctions (e.g., Hudson and Alberts 2004).

Following the 1990 re-discovery, Dr. Vogel and other local stakeholders formed the Jamaican Iguana Research and Conservation Group (JIRCG). With considerable technical and financial support from international partners, the JIRCG (re-named in 2006 as the Jamaican Iguana Recovery Group [JIRG]) implemented emergency actions (primarily nest site protection and diversion of charcoal burners away from the critical nesting areas) that likely prevented an otherwise certain extirpation of the remnant population. Also crucial, the nucleus of iguanas for a captive program for breeding and headstarting was collected between 1991 and 1993. Undeniably, 1990–1993 was a most critical period for the Jamaican Iguana (Vogel et al. 1996).

Subsequent conservation activities have focused on recovery efforts for the remnant population, securing protection for the Hellshire Hills, and establishing a reintroduced population on the Goat Islands (Wilson et al. 2004; Wilson 2011; Grant et al. 2013). This report represents an update and summary of research and conservation activities carried out over the 1990–2014 period. In addition to presenting recent conservation results, we also examine the extent to which overall project objectives have been achieved, and submit some recommendations aimed at ensuring the survival of this iconic species and the threatened "hotspot within a hotspot" for which it serves as a flagship species (e.g., Alberts 2000; Wilson and Vogel 2000; Lewis et al. 2011).

International significance for global iguana conservation.—Retrospectively, the Jamaican Iguana re-discovery generated an impressive collective impact on iguana conservation, and on reptile conservation in general. Following the exciting "re-discovery" news emanating from Jamaica in 1990, the U.S. zoo herpetological community selected Caribbean lizards for its fledgling reptile conservation programs and *Cyclura* species naturally emerged as a leading priority. The Jamaican Iguana presented a compelling cause around which to rally zoo support. Soon a small cadre of participating zoos was directing much needed financial, technical, and logistical support to the JIRCG's field research and conservation efforts. Over the next several years, that U.S.-based group managed to raise funds not only for the Jamaican Iguana program, but also channeled critical support to the Anegada and Grand Cayman Blue Iguana recovery programs that were also in their infancy. Zoo staff drew upon their media expertise to publicize this captivating "second chance, re-discovery to recovery" story, which helped attract the attention of the global conservation donor community and also galvanized involvement from additional zoos. In the 1990s, the Jamaican Iguana story was featured in numerous popular magazines, newspapers, and even prompted sponsorship from Nike, Inc. to create wear-resistant iguana vests for the first radio-tracking study (Hudson and Alberts 2004).

In 1993, local and international groups convened a workshop in Kingston, Jamaica, that brought most of the existing Caribbean iguana and conservation expertise together for the first time. Assistance from IUCN, International Union for Conservation of Nature, was enlisted to conduct a Population and Habitat Viability Assessment (PHVA), and a recovery plan was generated that outlined immediate action steps to recover the iguana (JIRCG 1993). This PHVA was the first for a lizard and only the second of many future analyses for reptile species. Alliances forged during the workshop soon led to the formation of the IUCN SSC West Indian Iguana Specialist Group in 1996, that later (2000) expanded its mandate to include all iguana genera. The Iguana Specialist Group (ISG) is today recognized as a global strategic leader for prioritizing iguana research, developing recovery programs, and mobilizing conservation action.

A second major iguana conservation group emerged in 2001, the International Iguana Foundation (IIF), in response to the paucity of financial resources available for iguana programs. With leadership from many of the zoos that had supported iguana conservation since the early 1990s, the nonprofit IIF quickly developed a revenue stream from previously unavailable sources that allowed improved planning and action for core-supported species, including *C. collei*. A small grants program has awarded proposals benefitting over 20 iguana species throughout their range. In the 13 years since inception, the IIF has raised close to two million USD, nearly all of which has been directed toward iguana conservation, research, and education programs in host countries (Hudson 2006).

Materials and Methods

Preamble.—Primary field methods (e.g., mark-release, headstarting) have been detailed elsewhere (Vogel 1994; Vogel et al. 1996; Wilson et al. 2004) and are not repeated here. Rather, we restrict our discussion to methods or approaches that were either novel (e.g., deployment of "Judas Iguanas") or significantly modified (e.g., headstarting and captive protocols), or that otherwise warrant special mention (e.g., predator trapping).

***Study site*.**—The Hellshire peninsula, located ~ 20 km west of the capital city of Kingston, consists of low-lying limestone hills covered in dry tropical forest. Boasting some sections that may never have been cut, the Hellshire Hills have arguably retained the largest intact (old growth) dry tropical forest in the region (McLaren et al. 2011). This remaining core of primary forest supports a rich collection of endemic plant and animal species, and encompasses the entire current range of the Jamaican Iguana (Vogel et al. 1996; Wilson and Vogel 2000; Wilson 2011). The Hellshire Hills is regarded as a "hotspot within a hotspot" (Lewis et al. 2011) – an exceptionally important biodiversity area within one of Earth's recognized biodiversity hotspots, the insular Caribbean (Myers et al. 2000; Mittermeier et al. 2005). The area is considered an Important Bird Area (Wege and Anadon-Irizarry 2008), a Key Biodiversity Area by the Critical Ecosystem Partnership Fund, and is listed by the Alliance for Zero Extinction as one of roughly 600 important sites worldwide that is facing an imminent extinction (see Ricketts et al. 2005; Grant 2014). Until the Jamaican government withdrew the application at the end of 2013, local agencies and major government stakeholders had worked for 15 years to declare the PBPA a UNESCO Biosphere Reserve (United Nations Educational, Scientific and Cultural Organization; Serju 2014).

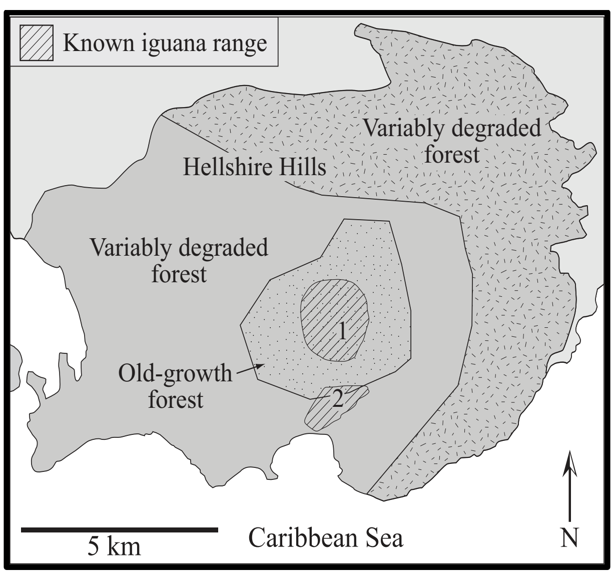

FIGURE 1. Habitat map of Hellshire Hills, Jamaica, with inset showing known area of occurrence for the Jamaican Iguana. (1) Main population; (2) Small subpopulation of one wild male individual and ~ 12 headstart individuals released in 2007. Note that habitat designations labeled here are transitory due to on-going loss and degradation of the Hellshire Hills forest; areas coded as "Variably Degraded" represent mosaics of degraded and highly degraded habitat, including those currently under assault from illegal tree cutting activities associated with the production of charcoal. Note also that the eastern portion (stippling) is more highly degraded, whereas the western portion (no stippling) contains larger tracts of recovering forest.

Although Jamaican Iguana surveys and field research have been conducted throughout the Hellshire Hills, conservation and research efforts have focused on the main population discovered in 1990. That core population is restricted to the most isolated and least disturbed section of the forest, ~ 12.5 km^2 in the south-central portion of the peninsula (Fig. 1).

***Population monitoring*.**—Our primary index of iguana abundance is the number of females using the two main communal nesting areas that were identified during surveys in 1990 (Vogel 1994; Vogel et al. 1996). Those sites were monitored intensively in 1991 and a count of nesting females was obtained (Vogel 1994); that assessment provides the best, indeed the only window into the demographic past of *C. collei*. Our analysis of population trends is based on referencing those 1991 data as a baseline and examining comparable data obtained for the period 2004–2013.

In addition to trapping efforts focused on female iguanas during the nesting season, observational and mark-recapture data were collected throughout other seasons. In particular, a live-trapping grid designed for predator control (see below) proved useful in augmenting behavioral observations and focused trapping efforts. Additional observational and capture data were obtained using camera traps (2008–2013) and in the context of radio-telemetry studies.

***Nest site monitoring: annual counts of nesting females*.**—Nest site monitoring consisted of daily observations during the nesting season (mid-May through June), using hides constructed adjacent to the main communal nesting areas (see Vogel 1994). The primary goal of nest site monitoring was to determine the number and location of nests within the primary, historically monitored nesting sites. The identity of nesting females was determined either by external marks (color-coded beads, paint marks) or after capture (primarily using baited cage traps) from their implanted transponders, although not all nesting individuals were captured or identified in a given year. Ultimately, an annual tally of nesters (nesting confirmed, or individual captured gravid in vicinity) was generated for the same communal nesting areas for which baseline data were collected in 1991.

***Indexing annual productivity: enumeration of hatchlings*.**—Obviously, the number of females depositing nests may not translate into population productivity if those nests are unsuccessful. Therefore, the number of hatchlings resulting from an annual nesting effort represents a better indicator of population viability. However, overall hatching success (the number of hatchlings produced) is influenced by multiple factors, including the number of females nesting, the size and fecundity of those females, and hatching success per nest.

In addition, the annual count of hatchlings is necessarily dependent on our ability to capture recently emerged individuals, and harvesting efficiency is influenced by environmental conditions, availability of human resources, seasonal preparation, and luck, all of which have been subject to variation. For example, nest site fencing rings were either damaged or efforts compromised by tropical storms and hurricanes, especially during the years 2004 (Ivan), 2005 (Dennis and Emily), 2007 (Dean), and 2008 (Gustav). Predators also occasionally damaged nest site fencing rings and hatchlings sometimes escaped through emergence holes dug under surround barriers. As a consequence, our measures of annual productivity include a substantial margin of error, but nevertheless provide a useful minimum index of overall productivity.

The only changes in hatchling collection protocol implemented in recent years (2005–2013) were improvements to the system of fencing used to protect nesting areas and facilitate the collection of hatchlings. The current system consists of using polyethylene "poultry curtain" as fencing, secured on the bottom interior with strips of rubber hosing staked into the substrate (Fig. 2). This method minimizes soil disturbance and erosion potential, and permits rapid repair or re-erection of fencing following storms. Hollow tubes and shade structures are placed within enclosures to facilitate harvesting and provide hatchlings with protection from direct sunlight and avian predators. Notably, nest site fencing rings have been erected increasingly early in recent years (currently ~ mid-August), as annual nesting has been initiated earlier.

Headstart-release and captive population.—The methods employed in the headstart-release program, including field collection of hatchlings, captive rearing, health screening, and repatriation, are detailed in Wilson et al. (2004). Some headstarting protocols were modified based on discussion and analysis during the Species Recovery Plan workshop held in 2006 (Grant et al. 2013) and those changes are appropriate to detail here. Modifications incorporated in recent years include: (1) collecting 40 wild hatchlings per year (up from 20) with a female bias; (2) improvements in diet and other aspects of husbandry; (3) optimizing occupation of the available (captive) space; and (4) the construction of additional rearing enclosures. Blood samples for genetic analysis are now primarily collected in the field from as many annual hatchlings as possible, both those that are transferred to Kingston's Hope Zoo for headstarting and those released after initial morphometric processing. All hatchlings were marked with implanted transponders or occasionally by toe-clipping when transponders were in short supply. An annual health screening of the entire captive colony now occurs in the spring before scheduled releases and prior to follicle advancement.

FIGURE 2. Nest site surround (4 x 6 x 0.8 m) for capturing hatchling Jamaican Iguanas at the "Upper Nest Site", Hellshire Hills. (Photographed by Rick Van Veen).

The *ex situ* U.S. zoo assurance colony has been managed according to methodologies developed for the sustainability of small captive populations by the Association of Zoos and Aquariums (AZA), and is based on the most sound genetic and demographic models available (Grant 2012).

Distribution surveys: deployment of Judas Iguanas.—To assess the population's full geographic range, surveys and associated research work have been conducted outside of the species' current (known) range of occupancy. Unfortunately, the rugged terrain and lack of water sources render ground surveys in interior Hellshire problematic, and result in a high ratio of effort to coverage (Woodley 1971). As a consequence, logistical obstacles have historically limited the number and scope of survey efforts in Hellshire's interior forest.

To enhance our chances of detecting new subpopulations or isolated individuals outside the known area of occurrence, we tested a new and promising survey strategy. Specifically, we adapted the "Judas Goat" approach (see Campbell and Donlan 2005; Campbell et al. 2005) and released zoo-reared iguanas outfitted with radio transmitters into areas east and west of the core population. Just as Judas Goats can be used to detect individuals at low density or to confirm the completion of an eradication campaign, we aimed to employ Judas Iguanas to detect scattered individuals or confirm absence.

Because iguanas interact socially (e.g., sexually, antagonistically, etc.), we assumed (based on prior experience with monitored releases) that radio-tagged animals released into novel areas would likely encounter and interact with any resident iguanas. Thus, Judas Iguanas could provide a mechanism for detecting wild iguanas under exceedingly low-density conditions in large expanses of rugged terrain. Evidence of wild iguana(s) can either be confirmed directly (observations of individuals or sign noted during radio-tracking) or indirectly; for example, males often bear the consequences

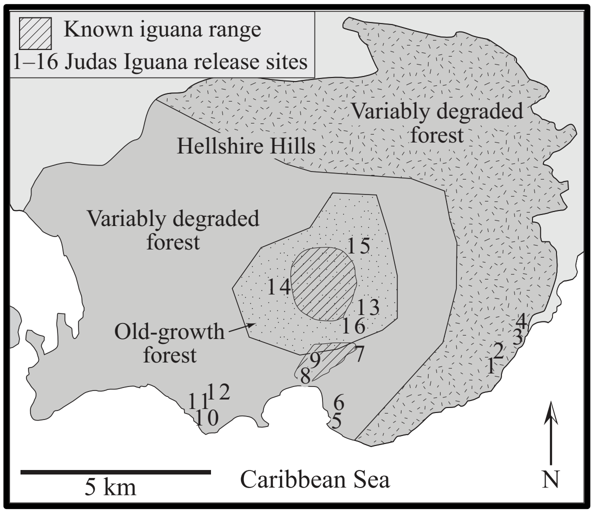

FIGURE 3. Locations of 16 Judas Jamaican Iguana releases in the Hellshire Hills, Jamaica. See Fig. 1 for a description of the "Variably Degraded" habitat designation.

(scars) of agonistic encounters, so evidence of recent fighting in a Judas male would indicate the presence of another male iguana.

We released a total of 14 Judas Iguanas (9 males, 5 females) outfitted with Holohil PD-2 radio transmitters (Holohil Systems Ltd., Ontario, Canada) spread among nine sites during 2008 and 2009. The 14 individuals ranged between five to 16 y, weighed between 900 and 3,450 g, and were radio-tracked for up to 189 d. Two individuals (both males) were re-captured and later deployed on another Judas mission; hence, Judas releases were conducted at 16 different locations within nine focal areas (Fig. 3).

Predator control.—We initiated a program to reduce impacts from non-native mammalian predators in May 1997. That mongoose-focused effort began with 20 live cage traps (32 x 12 x 10 cm) placed along a loop trail passing through the two primary (communal) iguana nesting areas (see Fig. 4). Traps were baited with salted fish and the effort was sporadically operational until January 1998, at which point trapping was conducted during every week of the year, with traps being open and operational ~ three days per week. In this early phase of predator control (1997–1999) traps were checked daily and inactivated for the several days of the week during which a worker was not present to conduct daily checks.

Due to on-going concern about high levels of mongoose predation and the apparent success of removal trapping in reducing mongoose abundance (see Lewis et al. 2011, and discussion below), a decision was made in 1999 to leave traps open and operational on a continuous basis, with traps being checked every 2–3 days, minimally, to release any iguanas captured unintentionally. With the singular exception of a several-week period during the early 2000s, this trapping regime has been operating every day since June 1999, and continues to the present (September 2014).

The trap-removal effort was expanded to include the deployment of up to ~ 300 traps, including stations established along new trapping trails that added a "Western Loop" in 2011–2012 and an "Eastern Loop" in 2013–2014. The combined trapping ring now surrounds the original (1997) trapping loop and increased the size of the predator-controlled area by over two-fold (Fig. 4). Beginning in the early-mid 2000s, the original traps (32 x 12 x 10 cm) were replaced with larger traps (80 x 30 x 25 cm). Larger traps enhance the potential for capturing larger invasive alien species (IAS) (e.g., cats and small dogs) and also reduce the risk of injury to native species such as the iguana and the Jamaican Coney. In addition to our primary use of live mesh box traps (above) we periodically deployed wire snares for larger IAS (e.g., pigs, dogs) and also experimented with leg-hold traps targeting cats.

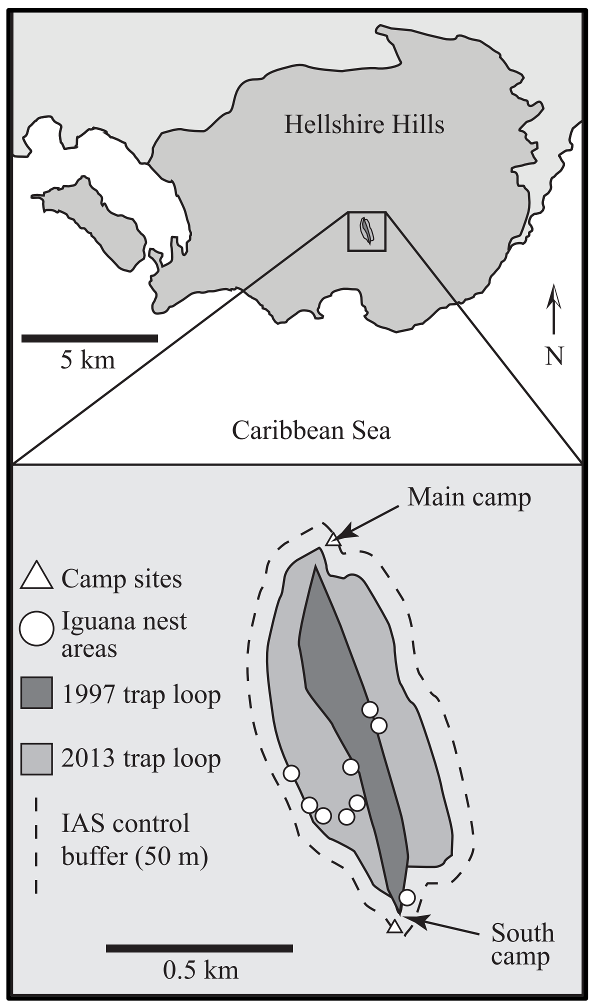

FIGURE 4. Core Jamaican Iguana area in the Hellshire Hills showing original (1997) invasive alien species (IAS) trapping loop coverage (dark grey) and more recent 2012–2014 trap loop expansion (lighter grey) with a 50 m buffer control area (dashed line).

Construction of artificial nesting sites.—In 2005, iguanas began nesting in a small vegetable garden (~ 2.5 x 1.5 m) at the main field station, demonstrating the potential utility of creating artificial nesting areas to compensate for the scarcity of suitable soil deposits in the species' current area of occupancy (Fig. 5A). In addition, significant crowding had become apparent at one of the two main communal nesting sites by 2009, as evidenced by nesting iguanas excavating previously deposited nests, resulting in reproductive failure for some early nesting individuals. To accommodate the increasing number of nesting iguanas, we constructed an artificial nesting site in 2011–2012 (Fig. 5B) located ~ 40 m south of the "Upper Nest Site", the more productive of the two main communal nesting areas (Vogel 1994). Due to the paucity of soil in Hellshire, we imported soil (by foot trail) from a site ~ 2 km north of the nesting area, drawing from an abandoned charcoal kiln in a slightly degraded section of the forest. Thus, the soil contained some charcoal residue but was viewed as acceptable, given the alternatives (local soil depletion or the introduction of potential pathogens or non-native plants via importation of soil from a more distant location).

Results

Population trends: nesting females and hatchlings at core, monitored sites.—The number of iguanas nesting at the core communal nesting sites has increased dramatically over the past two decades (Fig. 6). A maximum of nine females was observed in the vicinity of the two communal nesting areas in 1991, with six confirmed as having nested at those sites (Vogel 1994). In 2013, 53 females were documented as nesting or observed gravid in those same areas, representing a six-fold increase since conservation activities were initiated. In addition, 10 nests were recorded at nearby locations (within ~ 1 km of the main nesting areas), nearly all of which were deposited by repatriated headstarters. Two of these nesting areas did not exist in 1991 (the artificial nesting sites), and another two were probably not active in the preceding decades. Allowing these "new", primarily headstart nests to be included in our overall tally yields a 2013 total of 63 nesters in the core area, suggesting a seven-fold increase since 1991.

We cannot say for certain that iguanas are not nesting outside of our area of conservation focus, especially given the large number of headstarters that have been released into the core nesting area (*n* = 137 females as of 2015). However, the potential for successful nesting outside of the core, predator-controlled area seems remote due to egg and hatchling mortality attributable to IAS predators. For example, camera trap data verified 100% mongoose predation on 14 nests deposited outside of the predator-controlled zone during 2011–2012 (Rick van Veen, unpubl. data). As a consequence, nests not protected from mongoose predation in particular are unlikely to make a substantial contribution to future recruitment. Accordingly, the monitored communal nesting areas within the predator-controlled area probably account for most, if not all of the species' annual productivity.

The number of hatchling iguanas harvested has increased steadily since conservation and monitoring activities were initiated in 1991 (Fig. 7). And while some of this increase may be attributable to improved harvesting efficiency, the overall trend is clearly the product of increasing numbers of nesting females (see Fig. 6).

Distribution surveys: deployment of Judas Iguanas.—We released 14 individual Judas Iguanas; two of the large males were recaptured and released at second locations, resulting in 16 Judas Iguana releases to nine general locations. Twelve (eight male, four female)

Figure 5. (A) "Stumpy" (headstarted Jamaican Iguana released in 2001) nesting in a small vegetable garden at field station "South Camp", Hellshire Hills, in 2006. This inadvertent, artificial nesting area was constructed in 2005, and as of 2010 was supporting annual nesting by up to three Jamaican Iguanas. (B) Artificial nesting site constructed adjacent to the "Upper Nest Site". A nest excavation hole can be seen in the lower left portion of the image. (Photographed by Rick Van Veen).

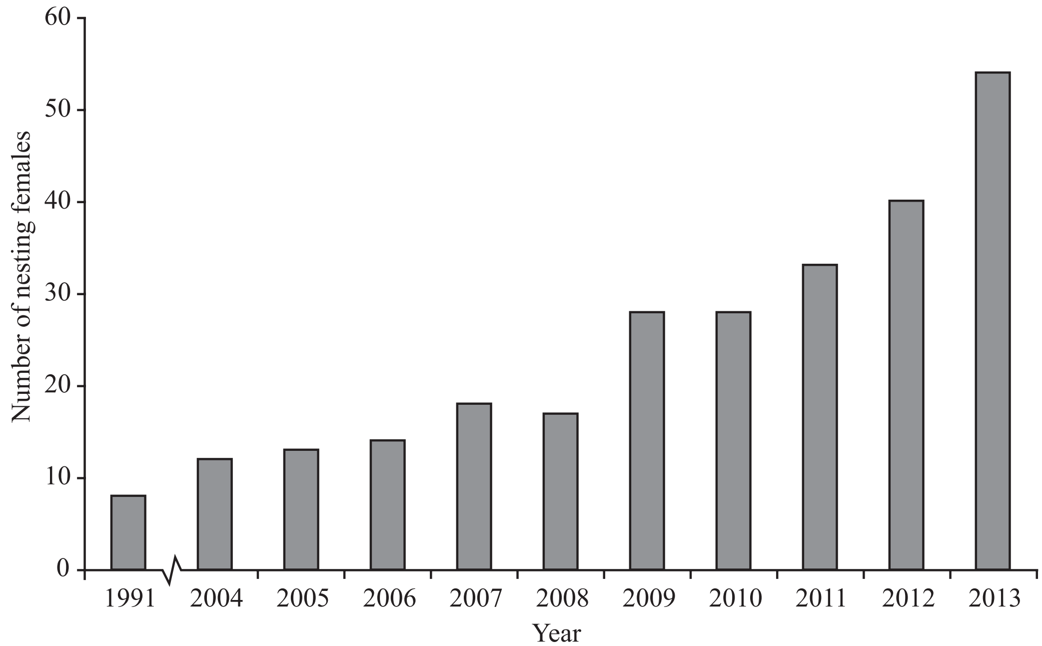

FIGURE 6. Estimated number of nesting females per year (= number of confirmed nests plus gravid female Jamaican Iguanas observed at monitored communal nesting sites in the Hellshire Hills between 1991 and 2013).

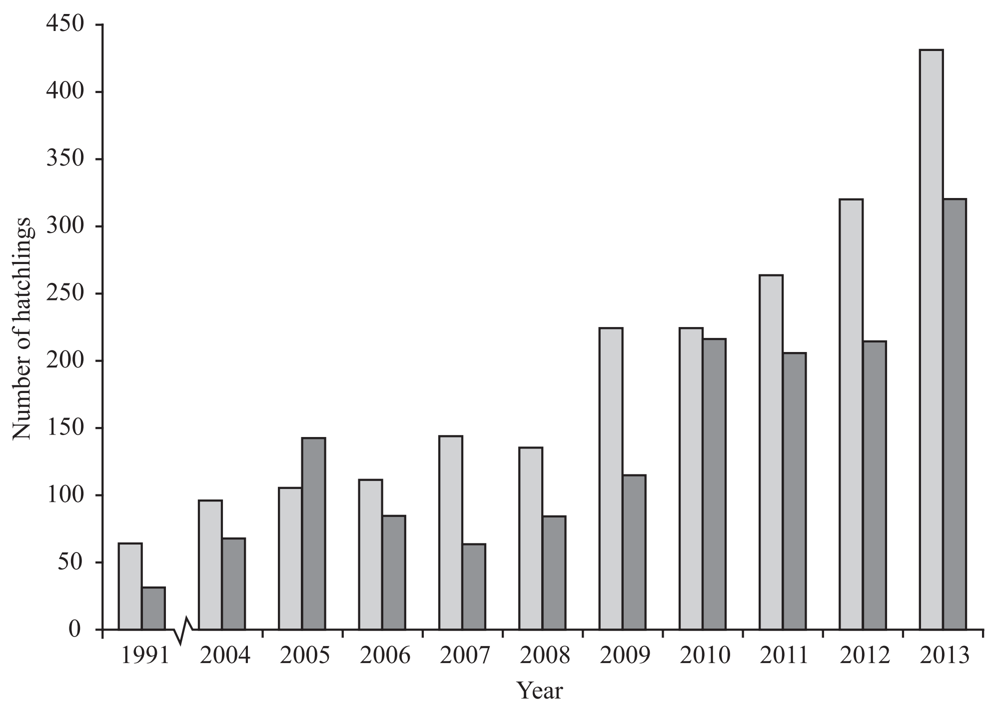

FIGURE 7. Number of captured/enumerated hatchling Jamaican Iguanas in the Hellshire Hills (dark grey) and predicted total number of hatchlings (light grey). Predicted numbers of hatchlings were based on the number of females nesting, and assumed an average successful clutch size of eight hatchlings per female. Although *C. collei* is known to produce clutches of up to 20, many of the recent (headstart) females were small and would have produced smaller clutches.

releases were in 2008 (7 February to 12 August) and four (three male, one female) in 2009 (5 May to 28 July). In all, we recorded 197 waypoints (sightings or confirmed locations) during subsequent radio-tracking efforts. With the exception of Judas Iguanas that entered the core iguana area and interacted with (known) resident iguanas, none of the Judas Iguanas appear to have contacted other iguanas. Associated ground surveys also failed to reveal any iguana sign outside of the known area of occupancy.

Using Judas Iguanas to assist in survey efforts shows considerable promise, albeit at significant risk to the individual iguanas deployed. For example, iguanas released in degraded forest near Hellshire's periphery are exposed to increased predation risk from IAS; Judas Iguanas released in eastern Hellshire were frequently chased by dogs and may explain the loss of at least one large male (Judas Iguana release #1). Various IAS were noted in the vicinity of all Judas release sites. Although only one of the six small iguanas (< 1,200 g) was a confirmed victim of predation, the remaining five were classified as "lost", but under circumstances suggesting that they were also victims of IAS predation.

Females, regardless of age or size, appeared to find a safe refuge and made only small forays from those locations. Large males on the other hand, were quite mobile, with all of the largest (> 2,000 g) males moving large distances. For example, Judas Iguana release #15 was released on the edge of the known iguana distribution, and after making several large forays returned to within the known iguana range. Another large male Judas Iguana was released to the east of the core area in the vicinity of a wild (unknown identity) male iguana; that Judas Iguana left his release site and was found some weeks later, 6.5 km away in a housing estate outside of the Hellshire forest (Judas Iguana release #7). That individual was captured and later released within the known iguana range where it was monitored until it lost its transmitter several weeks later.

Headstart and release.—In the initial years after the 1990 re-discovery, the majority of eggs/hatchlings observed in the Hellshire Hills were collected for headstarting at the Hope Zoo (1991–1994). For several years afterward (1995–2000), only a small number of hatchlings were headstarted, due to space and financial restrictions at the Hope Zoo, as well as a focus on other components of the recovery effort. Iguanas were released back to Hellshire beginning in 1996 with a pair of young adults, and repatriations have continued on a nearly annual basis ever since (Table 1). As released iguanas created space at the captive facility, the program aimed to collect 20 hatchlings per year through 2006.

To date, a total of 565 iguanas have lived some portion of their life at the Hope Zoo. Overall, iguana health at the headstart facility has been very good (Lung et al. 2002; Nancy Lung, pers. comm.), with only a very small percentage being lost to disease, trauma, or congenital defects. 16% have died or were reported as missing before being released. Most of the missing animals were believed to have been lost via cage breaches from hurricane damage or wear, and are assumed dead because of the abundance of non-native predators in the neighborhood surrounding the Hope Zoo.

During the annual health screen all captive iguanas are examined physically and measured for growth. At the time of the Species Recovery Planning (SRP) meeting in 2006 (Grant et al. 2013), available growth data indicated that most iguanas reached 1–2 kg in size between ages 6–8 years old, and some when as young as 4–5 years (additional details will be published elsewhere). Slow but consistent improvements in husbandry at the Hope Zoo have been accomplished over the years, resulting in improved (increased) growth rates. It was recommended by the SRP that if iguanas were afforded consistent access to high quality food, ample sunlight (cages kept clear of vine cover), numerous hides and visual barriers to separate conspecifics, and were housed at lower densities, their growth rates would increase (based on data from congeneric programs). With a density of 4–6 iguanas per cage and a female bias of up to 3:1 to minimize competition, most iguanas should be larger than one kg in the spring before their sixth birthday.

Further, if all cage space was optimized and additional cages constructed, the program could incorporate 40 new hatchlings and anticipate the release of 40 older headstarters per year. Collection in the field for this target began in 2007. Although husbandry recommendations have not been followed consistently, there has been improvement, particularly in the last several years. For example, only eight iguanas remained captive beyond their sixth birthday as of the release in March 2014. To date, a total of 278 headstarters (141 males, 137 females) have been repatriated back into Hellshire (Table 1).

During the first years of releases (1996–2001), the size at which an iguana would be safe from feral cat and mongoose predation was unknown. Ultimately, animals were released between 1,000–2,850 g (Wilson et al. 2004). In Anegada, where cats are the main predator, radio-tracked headstarted Anegada Iguanas were released between 414–2,050 g. While no strong correlation between size and survival was found during the first two years post-release, the smallest iguanas did not survive, suggesting that 400 g was still a vulnerable size class (Bradley and Gerber 2006). In the more remote release sites on Grand Cayman, iguanas are released at 2–3 years old, because native snakes are the main predator (Burton 2012). Most Jamaican Iguanas are not radio-tracked after release so their fate is unknown unless they are opportunistically observed or captured in cage traps in Hellshire, either caught incidentally in traps intended for mongoose or those intentionally set for recapture data (e.g., during nesting). However, during the Judas Iguana effort, a 900 g male released outside the predator-controlled area was found one month later under a bush with its intestines pulled through a 2.5 cm abdominal hole, characteristic of mongoose predation (Rick van Veen, pers. obs.). Since 2009, all non-Judas iguanas have been released in the core, predator-controlled area, and all were larger than 900 g.

***Off-island,* ex situ *program*.**—As a further hedge against catastrophic loss in the wild, 24 iguanas were exported in two groups of 12 between 1994 and 1996 to establish a collectively managed *ex situ* captive population in U.S. zoos (Central Florida, Sanford, Florida; Fort Worth, Texas; Gladys Porter, Brownsville, Texas; Indianapolis, Indiana; San Diego, California; Sedgwick County, Wichita, Kansas) (Grant 2012). Because zoos had previous experience breeding other *Cyclura* species, the exportation was expected to create a long-term sustainable reservoir of wild genetic diversity and provide an off-island assurance colony in the event of a decline or loss of the Jamaica-based population. In addition, iguanas in the U.S. population promote education and awareness, and generate funding and support for the ongoing recovery effort in Jamaica. Iguanas were paired according to their clutch assignments, which were determined initially by nest emergence in the field and later supported by microsatellite data (Davis 1996). However, allelic diversity was examined at only four loci in this preliminary analysis, so additional study will be required to characterize kinship and diversity within the *ex situ* population as a whole. Because the remnant wild population was so small and isolated for many years, relatedness in the U.S. captive group has probably been underestimated. Genetic analyses currently in progress are focused on retention and potential skew of diversity in

TABLE 1. Captive Jamaican Iguanas headstarted, released, and captive-bred at the Hope Zoo, Kingston, and U.S. zoos. Iguana numbers are in the format: Males.Females.Unknown sex (Total). *Two females confiscated from a zoo in St. Elizabeth have an unknown hatch date but were at least 10 years old in 2012.

Hatch Year	Transferred to Hope Zoo	Captive-Bred Hatches: Hope Zoo	Exported to the U.S.	Captive-Bred Hatches: U.S.	Year of Release	Released to Hellshire
UNK*	0.2 (2)					
1991	13.14.4 (31)		4.2 (6)			
1992	5.8 (13)		3.3 (6)			
1993	22.18 (40)		2.4 (6)			
1994	12.16.1 (29)		3.3 (6)			
1995	5.3 (8)					
1996	2.5 (7)				1996	1.1 (2)
1997	*none*				1997	3.3 (6)
1998	5.5 (10)				1998	5.7 (12)
1999	3.2 (5)				1999	4.3 (7)
2000	1.2 (3)				2000	*none*
2001	10.8 (18)	0.0.1 (1)			2001	6.7 (13)
2002	7.12 (19)			0.0.1 (1)	2002	*none*
2003	16.13 (29)				2003	5.4 (9)
2004	7.12 (19)	2.1.1 (4)			2004	0.2 (2)
2005	11.9 (20)				2005	7.9 (16)
2006	6.14 (20)			9.12.3 (24)	2006	*none*
2007	23.15.1 (39)				2007	9.9 (18)
2008	22.18 (40)				2008	13.7 (20)
2009	11.17.1 (29)				2009	7.14 (21)
2010	23.29 (52)				2010	8.4 (12)
2011	14.26.3 (43)				2011	8.9 (17)
2012	14.32 (46)			3.3 (6)	2012	7.12 (19)
2013	8.34.1 (43)			9.7.2 (18)	2013	30.22 (52)
2014	12.16 (28)			0.0.24 (24)	2014	15.14 (29)
2015	*to be determined*				2015	13.10 (23)
TOTAL	252.330.11 (593)	2.1.2 (5)	12.12 (24)	21.22.30 (73)		141.137 (278)

the wild population, especially due to the influence of the headstart-release program (Mark Welch, pers. comm.).

In the first decade of the recovery program, *C. collei* proved to be more reluctant to breed in captivity than other *Cyclura* species. A single hatchling was discovered in one of the headstart cages at the Hope Zoo in 2001, representing the first captive breeding for the species. That hatchling was smaller than the average seen in the wild and did not live beyond one month. In 2004, a second group of four hatchlings was discovered in the headstart facility, three of which thrived and have since been released. Despite attempts to improve the Hope Zoo's two exhibit cages to promote breeding with visual barriers, soil suitable for digging burrows, and hides, the pairs have not reproduced and have at times seriously injured each other during agonistic encounters. It is likely that breeding is disrupted by the stress of numerous exhibit visitors and/or iguanas should be separated except during the breeding season or housed in much larger enclosures. In the successful Grand Cayman captive facility, pairs of iguanas are kept together year-round only in pens that are substantially larger than those available at the Hope Zoo (Fred Burton, pers. comm.).

Captive breeding in the U.S. first occurred at the Indianapolis Zoo in 2002, although the single hatchling died before completely exiting the shell. In 2006, the same dam and sire produced 20 hatchlings, in addition to four hatchlings produced by a second dam. Zoo staff concluded that mimicking Jamaica's seasonal environmental parameters such as photoperiod, temperature, and humidity, as well as reducing the animal's contact with humans, were the keys to reproductive success (Searcy et al. 2009). Unfortunately, since the death of that sire, the females have not reproduced successfully with their new mate. In 2004, Zoo Miami joined the AZA *Cyclura* program and three iguanas were transferred there, followed by two more in 2009. Two of the females in Miami produced a total of six hatchlings in 2012, 10 in 2013, and 16 in 2014. Second-generation dams at the San Diego Zoo Institute for Conservation Research and the Sedgwick County Zoo also produced one and seven hatchlings, respectively, in 2013, and eight hatchlings were produced in 2014 at Sedgwick. 63% of the clutches hatched in August, 25% in September, and 13% in October, which is similar to seasonality in Jamaica.

Almost all female iguanas in the U.S. have laid infertile eggs, and most have done so annually. Copulation is not always observed (including when clutches are successful) and it is unclear whether the lack of reproduction is behavioral, environmental, or a combination of both. The youngest dams to reproduce in the U.S. were second-generation females at 6.5 years old, and either 6.5- or 7.5-year old headstarters at the Hope Zoo. The oldest dam to reproduce was 20.5 years old in Miami (2014); she was 18.5 years old when her first successful clutch was laid. It is unknown how long Jamaican Iguanas can live or remain reproductively active, but a related species (*Cyclura lewisi)* has lived to at least 69 years of age, and although that individual never sired offspring, it was observed to have healthy sperm upon death (Barbara Durrant, pers. comm.). Six of the original 1991 hatch year iguanas are still captive (two in the U.S., four at the Hope Zoo), one of which has reproduced successfully. Two of the oldest females known from the original (early 1990s) nesting group were still alive and nesting in 2012 and 2013, suggesting a minimum reproductive age of at least 27 years.

Non-native predator control.—Beginning with 20 traps in 1997, and ultimately expanding the effort to include ~ 300 traps by 2014, our live cage trap program resulted in the removal of well over 1,500 non-native (IAS) predators, primarily mongooses (> 90%) based on > 350,000 trap days (one trap open for 24 h = one trap day). Larger IAS (e.g., wild pigs and dogs) have been removed by whatever means were available in the field, including the use of wire snares.

Early predator control efforts (1997–1998) indicated that local mongoose density could be reduced rapidly by implementing a trap-removal program. An initial capture rate of seven mongooses per 100 trap days (1 trap day = 1 trap open for 1 d) was reduced by more than an order of magnitude (to 0.25 per 100 trap days) after initial clearance (Lewis et al. 2011). Current trapping efforts result in the removal of > 150 mongooses per annum, primarily males, and the core area is considered clear of resident mongooses but serves as a sink for individuals dispersing or making extra-territorial forays.

Although feral cats were trapped and removed with some regularity, they are not as easily trapped as mongooses. Some cats avoid cage traps, such that other trapping techniques are required for their removal (Tolson 2000; Nogales et al. 2004). For example, we trapped and removed only 17 cats between November 2012 and October 2013, compared to 156 mongooses during that same one-year period. Dogs represent an occasional, recurrent threat that can result in significant demographic impacts because they are the only predators capable of killing adult iguanas. When dogs have come into and remained in the core iguana area, removal attempts have been initiated. For example, around 10 dogs were removed during the 2004–2013 period, primarily using snares.

Incidental take of native wildlife.—As anticipated, our trapping efforts resulted in some incidental take of non-target species. In 17 years of live box trapping (> 350,000 trap days) we documented only two instances of injury or death to iguanas. Reporting those unfortunate occurrences is important and provides an opportunity to inform future predator control efforts. In one case, a dog mauled a trapped iguana from outside of the trap, resulting in the loss of part of the iguana's tail and several toes; that individual was taken to the Hope Zoo for recovery and was later returned to its territory in the Hellshire Hills. One death occurred when a predator tampered with the trap, moving and exposing it to direct sunlight, which led to the death of the trapped iguana. Leg-hold trapping trials also resulted in the death of one iguana, bringing the project's 17-year total to two instances of non-target, threatened species loss.

Other non-target casualties of the trapping program included a few birds, land crabs, and hermit crabs. Importantly, we did not record any injuries or losses to other threatened species, such as the Jamaican Coney or the Jamaican Boa; individuals of those species were all released unharmed after capture.

DISCUSSION

Current distribution.—Our delineation of the current range of *C. collei* is based on observations (> 2,500) of individuals and sign (e.g., scat, trails), and represents the confirmed area of occupancy (Fig. 1). Although the existence of unknown satellite individuals or subpopulations is a possibility, available information suggests this is unlikely and that the core population under conservation management is the only remaining wild population of the Jamaican Iguana. This remnant population is restricted to a small area of (~ 1.18 km^2), with a second, minor concentration consisting almost exclusively of headstarters occupying a smaller area (~ 0.22 km^2) to the south of the main population (Fig. 1).

This core iguana zone is located in the middle of what is considered Hellshire's highest quality old growth forest – an area of around 12.5 km^2, or about 10% of Hellshire's total area. Overall, a total area of less than 1.5 km^2 appears to support essentially the entire (certainly over 90%) presumed remaining *C. collei* population. Unless the area of occupancy can be expanded significantly or a second population established in an additional location, the Jamaican Iguana will always be considered Critically Endangered by the IUCN Red List of Threatened Species (Grant et al. 2010; Baillie and Butcher 2012).

Survey efforts in 1990 in the Hellshire Hills also identified a small subpopulation located ~ 3 km west of the main population. Two active holes and one iguana were sighted, suggesting a small concentration consisting of only a few individuals (Vogel et al. 1996). Subsequent survey efforts in western Hellshire (1999, 2008) failed to detect any sign of resident iguanas, and complementary efforts employing Judas Iguanas also failed to reveal any sign of the species. Accordingly, the western sub-population is assumed extirpated. However, survey work in wider Hellshire, and attempts to locate iguanas in western Hellshire in particular, have not been exhaustive, so additional effort is warranted. While informative, our Judas Iguana efforts also did not cover the entirety of the Hellshire Hills, so the deployment of additional Judas Iguanas to the west and elsewhere is recommended.

Population status.—Though influenced by variation in harvesting success, the number of hatchlings enumerated annually has increased regularly and dramatically over the years, in concert with the increasing size of the nesting population (see Figs. 6 and 7). Also notable has been the use of artificial nesting sites, with up to three females making annual use of a small abandoned vegetable garden site, and two nests known at the large newly created site since 2012. This represents a significant enhancement of nesting potential, and an approach that could be further exploited to increase productivity in the core area and to expand the current distribution of iguanas. Considering the high failure rate of rock hole nests documented by camera traps, the limited availability of optimum nesting soil in Hellshire is likely to restrict future iguana population growth.

Between 1991 and the early 2000s the core nesting population consisted of perhaps a dozen older adult animals. For example, 11 females were recorded as nesting in 1999 (JIRCG, unpublished data), a number very close to the nine documented as nesting (or observed gravid in the area) in 1991 (Vogel 1994). Up through 2003, no new (young adult) wild recruits had been observed. The first such wild recruit (PIT-tagged and released as a hatchling, and survived to adulthood) to the nesting population was documented in 2008 for a female that hatched in 2004, and may have been the first wild recruit in over a decade, as well as the youngest female known to have nested successfully. Also by 2004, headstarters were beginning to comprise a significant proportion of the nesting population (28%). By 2013, headstarters comprised ~ 80% of the nesting population, with remnants of the original (1990s) cohort and a small number of recent wild recruits making up the remainder (Fig. 8).

The recruitment of new wild females into the nesting population has been far less dramatic than the accelerated enlistment resulting from the repatriation of headstarters. We know of only four females that matured in the wild and nested successfully, but this is significant and presumably reflects improved juvenile survival prospects owing to predator control. However encouraging, the small number of wild recruits underscores the persistence of high mortality on hatchling and juvenile iguanas, and the population's dependence on continued predator control efforts and sustained headstart releases.

Implications of Global Climate Change.—Jamaica's recent climate history has followed global and Caribbean trends of warmer temperatures, increased frequency of rainfall extremes and storm events, and rising sea levels (CSGM 2012). Mean annual temperatures are projected to increase by 2.8–4.3° C for the region that includes the Hellshire Hills, and the current drying trend is predicted to be most extreme (28–52% annual decrease) in the eastern part of the island. Increased temperatures have already been implicated in tropical lizard extirpations (Sinervo et al. 2010), and decreased rainfall negatively impacts lizard populations by reducing growth rates and productivity through a reduction in food and moisture availability (e.g., Tanaka and Tanaka 1982; Vogel 1984; Holmgren et al. 2001). Tropical storms and hurricanes can have immediate and delayed effects on species and habitats (e.g., Lugo 2008; Zimmerman et al. 2014).

This climate change scenario is not encouraging, and could have negative consequences for the iguana in the present century. Obvious mitigation measures include eliminating tree cutting and halting the construction of new roads or other developments in Hellshire. In addition, conserving coastal mangroves will help maintain the quality of coastal habitats that served as iguana habitat before the species became restricted to the rugged limestone interior. Such coastal habitats contain abundant nesting habitat (e.g., sandy soils) and represent prime areas into which a recovering iguana population could expand. Rather than presenting another stumbling block to the iguana's recovery, the specter of climate change should catalyze more definitive action to combat illegal tree cutting and other threats to Hellshire, and perhaps even improve environmental conditions in the short term.

Assessing project efficacy: addressing major threats to the iguana's persistence.—Woodley (1971) was the first to articulate clearly the major threats to the iguana's survival: (1) non-native mammalian predators; (2) illegal tree cutting and production of charcoal; and (3) large-scale development projects. Woodley (1971) also formalized the concept of restoring the Goat Islands through IAS eradications and selected species introductions. Those same major threats, as well as the Goat Islands restoration proposal, were reiterated in the original conservation strategy for the species (Vogel et al. 1996), and have been highlighted in all subsequent management or recovery plans for the species (e.g., NEPA 2003; Grant et al. 2013). Appropriately then, we briefly summarize progress in mitigating those well-known threats, and also report on developments relating to the long-awaited re-establishment of an iguana population on the Goat Islands – an effort that is "arguably the most decisive single action that can be taken to safeguard the species from extinction" (Wilson 2011).

Threat (I): IAS predators. Our predator control program has been effective at reducing the density of the mongoose in particular, and in combination with headstarting, appears to have been responsible for the remarkable population growth of the Jamaican Iguana. We therefore advocate similar control programs to recover threatened (prey) species in cases where resources are available for *in situ* conservation efforts. And while the cost and effort required for implementing a trap-removal program can be considerable, an appropriately scaled effort can be incorporated into an existing *in situ* conservation program with little additional cost. The work required to maintain a trap-removal campaign is not appealing to all field personnel, which perhaps accounts for the paucity of previous control efforts, even in cases where IAS predators have been identified as the leading cause of a species' endangerment. Appropriately conducted live cage trapping (with targeted removal) not only reduces the impact of IAS, but can also provide a useful technique for monitoring populations of threatened species.

Although live cage trapping has proven to be extremely effective in reducing the density of the mongoose, feral cats remain a serious problem in Hellshire. Current cage trapping efforts are effective at removing some but not all cats, and those that remain represent a significant threat to young iguanas and other threatened wildlife species. Our limited use of leg-hold traps targeting cats was effective, but also resulted in the incidental death of an iguana. Hence, in the absence of a significant increase in resources and trained personnel to deploy and check traps regularly, a sustained leg-hold trapping campaign is beyond the project's current capacity; this, owing to the high risk to non-target species during both the day (e.g., iguana) and at night (e.g., Jamaican Coney). However, pulsed leg-hold trapping efforts conducted over discrete time periods could be extremely effective, especially if conducted by expert trappers during optimal season(s). Overall, we advocate the continued use of live cage traps, especially given their utility in monitoring the iguana population

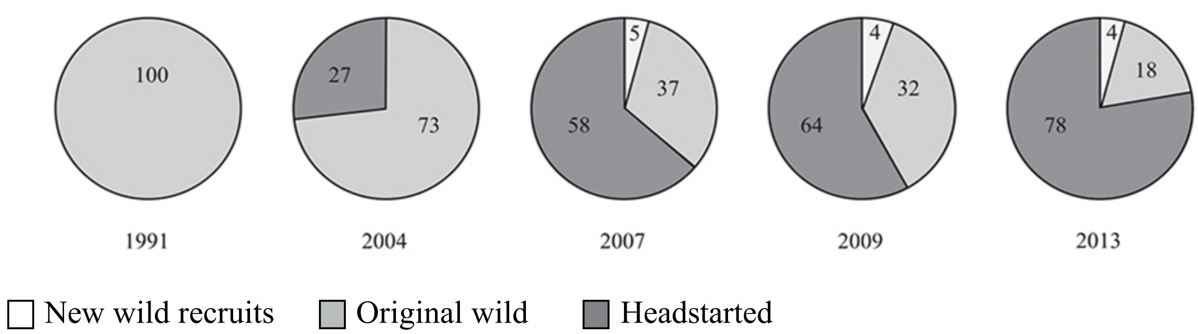

FIGURE 8. Changes (shown as percentages) in the composition of nesting Jamaican Iguanas in the Hellshire Hills between 1991 and 2013. Data include only females accurately identified and do not reflect numbers of estimated nesters in Figure 6.

(e.g., > 350 captures in 2013), and the relatively low risk posed to non-target species. In addition, current cage trapping efforts could be improved through camouflaging or burying traps, or by the use of other techniques known to enhance the success of trapping efforts targeting feral cats (e.g., pre-baiting, use of attractants). Finally, emerging technologies for taxon-specific toxicants or bio-control agents should be consulted as an obvious component of any adaptive conservation plan for the Jamaican Iguana.

Threat (II): Charcoal burning. Illegal tree cutting associated with charcoal production continues to degrade remaining intact portions of the Hellshire forest, and the prospects for active enforcement of existing laws seem as elusive in 2014 as ever before, despite Hellshire and the Goat Islands being included in the recently (1999) declared PBPA. Not surprisingly, both of the entities that were delegated management authority for the PBPA submitted management plans that included measures to protect the remaining Hellshire forest from tree cutting associated with charcoal production. To date, unfortunately, protection and enforcement efforts on the part of the delegated managers have ranged from woefully inadequate to altogether absent. In 2012, chain saws were heard from the field station ("South Camp") for the first time in the project's history, and in 2013 active charcoal kilns within 1 km of the core iguana area were documented from a helicopter (Fig. 9; van Veen et al. 2014). Though both incidents were reported to the authorities, no effective action was ever taken. Similarly, reports of commercial-scale charcoal production elsewhere in Hellshire have failed to elicit effective enforcement response from the relevant management authorities (Fig. 9).

Threat (III): Large-scale development projects. Despite the declaration of protected status for the PBPA in 1999, inclusive of the iguana's entire remaining Hellshire habitat and both of the Goat Islands, the area continues to be considered for large-scale development projects promoted by the Jamaican government – projects that would result in massive habitat loss and degradation, and likely lead to the iguana's extinction in the wild.

Development, primarily for housing, has continued on the eastern side of Hellshire since the 1960s. Fortunately, government plans (also dating back to the 1960s) to construct a large community in the center of Hellshire never came to fruition, and development has generally been restricted to the vicinity of roads created decades ago. But proposals for large-scale tourism along Hellshire's isolated, central beaches have surfaced with some regularity in recent decades. Those beaches fringe the iguana's remaining habitat, and even modest development along the coast would likely doom the iguana due to the construction of access roads and the resulting influx of both people and IAS predators (see Iverson 1978).

The "Goat Islands Project": Biodiversity refuge or Chinese mega-port?—The rehabilitation of the Goat Islands through IAS eradications and the re-introduction of the iguana has long been viewed as perhaps the only hope for ensuring the persistence of the species in the wild. This is the view shared by local experts in Jamaica and by international conservation and iguana researchers (e.g., the IUCN SSC Iguana Specialist Group). First articulated in the "Woodley Report" (1971), the Goat Islands restoration project has: (1) appeared in every subsequent species recovery plan for the iguana (e.g., Vogel et al. 1996; Grant et al. 2013); (2) been featured in various management plans for the PBPA; and (3) is listed as a high priority objective in the Jamaican government agency's National Strategy and Action Plan on Biodiversity (NEPA 2003). The overall restoration effort would include re-introduction of several other threatened endemic species (e.g., Jamaican Coney, Jamaican Skink,

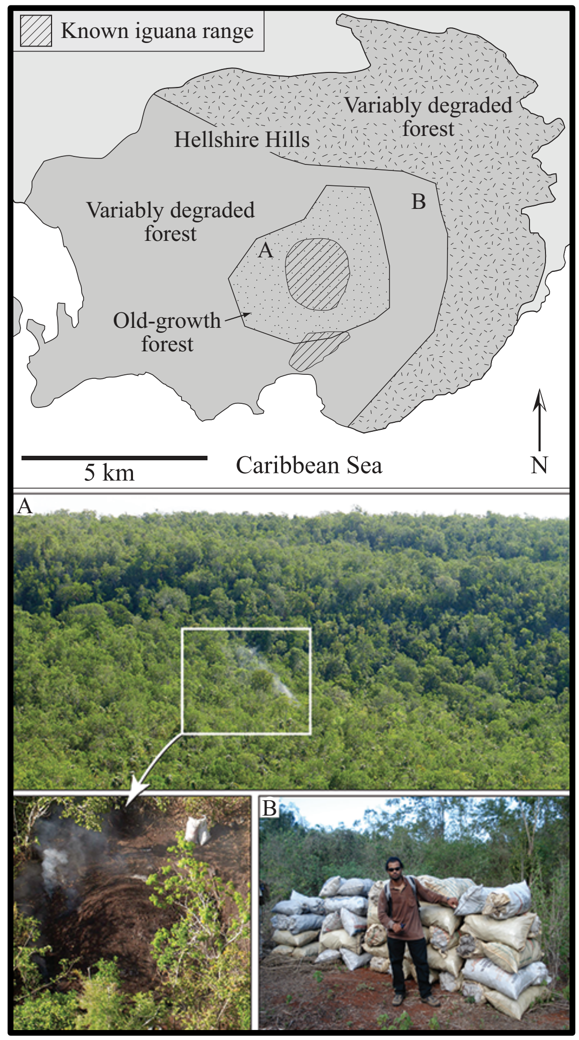

FIGURE 9. Active charcoal kiln less than one km from the core Jamaican Iguana area in western Hellshire in 2013 (A), and evidence of commercial charcoal production in eastern Hellshire in 2011 (B). See Fig. 1 for a description of the "Variably Degraded" habitat designation. (Photographed by Jeremy Francis (A) and Machel Emanuel (B)).

Jamaican Boa, and Blue-tailed Galliwasp). Removing IAS predators such as the mongoose from the islands would also benefit threatened migrating and resident bird species in the area (Island Conservation, Report to the Urban Development Corporation 2007). This restoration would have constituted the most significant single conservation intervention ever achieved in the Caribbean region and could have generated significant ecotourism benefits.

Unfortunately, recent development proposals have threatened the implementation of this obvious, long-acknowledged conservation imperative. The islands themselves are under government control/ownership, and their use and future is assigned to the Urban Development Corporation (UDC). The UDC is a quasi-government (i.e., government-appointed board) entity and is responsible for the management and development of the island's government-owned properties. In spite of lobbying by the JIRG and international conservation organizations (including the IUCN) over many years, the UDC was ultimately not willing to support initiatives aimed at creating a biodiversity reserve on the Goat Islands; rather, various plans to develop or sell/lease the islands were apparently considered, often surfacing after a change in the elected government and the resulting change in the composition of the UDC Board.

The most recent proposal involves the sale or lease of the Goat Islands and adjacent lands, possibly including sections of western Hellshire, to a state-run Chinese development company, China Harbour Engineering Company (CHEC; Goldenberg 2014; Grant 2014; Moore 2014). There have been reports in the international media that CHEC's parent company, China Communications and Construction Company (CCCC) is currently black-listed by the World Bank under its Fraud and Corruption Sanctioning Policy (Sri Lanka Guardian 2014; The World Bank 2011; Conniff 2014). CCCC appears on the list of firms barred from World Bank-financed contracts (The World Bank. 2014. Debarred and Cross-Debarred Firms and Individuals. Available from http://web.worldbank.org/external/default/main?theSitePK=84266&contentMDK=64069844&menuPK=116730&pagePK=64148989&piPK=64148984 [Accessed 25 September 2014]). Both Jamaica and China have received "unfavorable" ratings on the International Corruption Perception Index (Transparency International. 2014. Corruption Perception Index Available from http://www.transparency.org/research/cpi/overview [Accessed 29 August 2014]; see Boxill et al. 2007).

Although few specific details about the planned development have been announced (as of September 2014), the CHEC plans would apparently involve the conversion of the Goat Islands and its surrounding mangroves and coral reefs, into a massive transshipment port capable of accommodating the "New Panamax" ships in anticipation of the expanded Panama canal and proposed Nicaraguan canal (also a Chinese consortium development impacting protected areas; Hance 2014). Portions of the Hellshire mainland to the east and northeast of the Goat Islands would be incorporated into repackaging facilities and other industrial components of this port and the island's planned "logistics hub" initiative. If allowed to proceed, this project would completely destroy the Goat Islands, and the associated impacts on adjacent Hellshire would be severe. At the time of writing, NEPA has issued a license to CHEC for initial geotechnical investigation in the area and survey work has begun (see http://www.savegoatislands.org). Ultimately, this development would likely precipitate a cascade of extinctions and cripple the island's largest "protected" ecosystem.

Recommendations

***(1) Continue current* in situ *and* ex situ *conservation efforts*.**—*Cyclura collei* is regarded as "conservation dependent", and in the absence of current management interventions (e.g., predator control, headstarting) the remnant population would likely be extirpated in the near future, perhaps within decades. Accordingly, continuation of high priority objectives for field and captive management (Grant et al. 2013) will be necessary to safeguard the species in the short term.

***(2) Initiate Goat Islands restoration and iguana re-introduction program*.**—Long considered the only realistic hope for the Jamaican Iguana's persistence in the wild, this rehabilitation project should be commenced with urgency – especially given the unchecked threats to the iguana's remnant habitat in the Hellshire Hills.

***(3) Enforce existing laws (e.g., Forestry Act, NRCA Act) in Hellshire Forest Reserve*.**—This is a government mandate, and is the single most important and conspicuously absent component of the recovery effort.

***(4) Construct additional nesting sites in the predator-controlled core iguana zone*.**—The proven success of artificially constructed nesting sites, together with increasing competition for nesting access at existing (natural) areas, suggest that the construction of additional artificial nests would improve nesting success and further accelerate population growth.

***(5) Conduct additional surveys to delimit the iguana's area of occupancy*.**—As an on-going exercise, surveys outside of the core area should be continued in an effort to detect previously unknown individuals or subpopulations, and to assess the possible establishment of repatriated headstarters that migrated away from their original release sites in the core area.

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Byron Wilson is a herpetologist and conservation biologist at The University of the West Indies, Mona (Jamaica). Byron received his undergraduate degree in Zoology from the University of California, Berkeley, and his Ph.D. in Zoology from the University of Washington. He moved to Jamaica in 1997 to work on the Jamaican Iguana recovery project and after several years as a Research Fellow, was hired as a Lecturer in 2001, and later promoted to Professor. His research has focused on the conservation of the island's threatened species and natural habitats, particularly the Jamaican Iguana, serving as Head of the Jamaican Iguana Recovery Group from 2005 through 2013. Current projects include the ecology of the American Crocodile, the status of the endemic Jamaican Slider Turtle and the island's endemic amphibians, and long-term monitoring of dry forest fauna in the context of a predator control experiment in the Hellshire Hills. Additional collaborations include a MacArthur Foundation project focusing on the ecology and conservation of the Cockpit Country and Black River Lower Morass, and forest ecology studies in Hellshire and the John Crow Mountains. (Photographed by Jan Pauel).

Tandora D. Grant received a bachelor's degree in Biochemistry and Molecular Biology from the University of California, Santa Cruz. Currently a Research Coordinator at the San Diego Zoo Institute for Conservation Research, her work has focused primarily on conservation recovery strategies for Caribbean iguanas, San Clemente Loggerhead Shrike, and the San Diego Coast Horned Lizard. Tandora serves as Program Officer for the IUCN SSC Iguana Specialist Group (ISG), as well as Red List Authority evaluating the conservation status for all iguana species. She is the Species Coordinator and Population Management Advisor for the AZA Species Survival Plans for Jamaican and Grand Cayman Blue Iguanas. Having developed studbooks for these species, she assesses genetic and demographic statistics to determine optimum captive breeding pairs and release candidates. She is incorporating molecular data in this analysis to further define the fitness of reintroduced populations and guide management actions. Most recently, she developed websites for the ISG, International Iguana Foundation, and the Save Goat Islands site providing information opposing development in Jamaican Iguana habitat. (Photographed by Jeffrey Lemm).

Rick van Veen has worked with iguanas for more than a decade. He is an avid herpetologist, interested in natural history, ecology, invasive species ecology and management, conservation biology, and *in situ* conservation. He has worked with a diverse range of wildlife including crocodiles, sea turtles, frogs, snakes, macropods (kangaroos and wallabies), bats, seals, and penguins. He is also interested in feral animal management and has experience controlling exotic populations of pigs, cats, rats, mongoose, and dogs. Rick holds a Bachelor's of Zoology/Botany degree in Conservation Biology and Land Management from James Cook University, Townsville, Australia. Currently, he is a Ph.D. student at the University of the West Indies, Kingston, Jamaica, studying the ecology and conservation of the remaining wild population of the critically endangered Jamaican Iguana, *Cyclura collei.* Most recently, Rick has been working in Fiji with native Pacific Iguanas (*Brachylophus* sp.) and conducting eradication trials on the recently introduced invasive Common Green Iguana (*Iguana iguana*). (Photographed by Tandora Grant).

RICK HUDSON earned a bachelor's degree in Biology from the University of Richmond in 1977 and began his career at the Fort Worth Zoo in 1980, where he has spent the past 34 years, first as Curator in the herpetology department, then moving to conservation and science in 2000. He was active in mobilizing reptile conservation programs under the Association of Zoos and Aquariums (AZA) and chaired their Lizard Advisory Group and Rock Iguana Species Survival Plan for many years. He also co-chaired the AZA Crocodile Advisory Group and the Field Conservation Committee. A long-time champion for West Indian Iguanas (*Cyclura*), most notably the Jamaican Iguana, Rick helped organize the Iguana Specialist Group in 1997 and served that group in a leadership capacity for many years. In 2001, he led the organization of the International Iguana Foundation (IIF) to provide sustainable funding to critical iguana conservation programs and today serves as their Executive Director. Since forming, the IIF has raised nearly $2 million for iguana conservation and supports programs throughout the Caribbean, Central America, and Fiji. (Photographed by John Binns).

DAWN FLEUCHAUS began her career as a zookeeper over 20 years ago. She received her Bachelor of Arts in Biology and Biological Aspects of Conservation from the University of Wisconsin, Milwaukee (1993). She developed skills in animal observation and handling at the Racine Zoo overseeing large cats, wolves, hoofstock, birds, and a variety of herps and small mammals. For the past 16 years, Dawn has worked as a Zookeeper and Area Supervisor at the Milwaukee County Zoo. She worked for a number of years in the small mammals building, then as the animal hospital area supervisor. She has been Area Supervisor of the North America and Australia areas for the past 11 years. She has been a member of the American Association of Zookeepers, the Association of Zoos and Aquariums, and the International Marine Animal Trainers Association. Through the generous support of the Milwaukee County Zoo and the Zoological Society of Milwaukee, Dawn has work with the Jamaican Iguana Recovery Group since 2002. Her annual fieldwork includes assisting in behavioral monitoring, morphometric data collection, and blood sampling. (Photographed by Kimberly Stephenson).

ORLANDO ROBINSON received a bachelor's degree in 1994 in Botany and Zoology from the University of the West Indies, Jamaica, and a master's degree in Natural Resource Management from the Universidad Nacional Pedro Henriquez Ureña, Santo Domingo, Dominican Republic, in 1999. He has been with Hope Zoo since August 2000, where he started as the Assistant Curator and a year later as the Curator. During his tenure at the Hope Zoo, he has seen various management changeovers from management by the central government to that of a non-governmental organization. Orlando's major role as curator has been the strategic development of the Hope Zoo's master plan with special emphasis on strengthening conservation, research, and education programmes both locally and internationally, through involvement with various stakeholders. His involvement with the Jamaica Iguana Recovery Group has been through the headstart programme where he oversees the husbandry of the captive-reared population, including the collection of biometric data. (Photographed by Nancy Lung).

KIMBERLY STEPHENSON received a bachelor's degree in Zoology and Environmental Physics from the University of the West Indies, Mona, and is currently a Ph.D. student whose work seeks to model the impact of climate change on arthropods and small reptiles in the dry limestone forest of the Hellshire Hills. As a graduate student, she conducts research through two research groups based at UWI, the Climate Studies Group, Mona (CSGM) and the Jamaican Iguana Recovery Group (JIRG). Her work with the CSGM has assessed climate across the Caribbean region using a number of observed and modeled data sources, and she currently assists with managing JIRG field operations in the Hellshire Hills. (Photographed by Dawn Fleuchaus).