The Biology and Distribution of *Iguana delicatissima* on St. Eustatius.

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21st July – 23rd November, 2015

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Thesis code: BHE 70324 -39

List of Acronyms

DCNA	Dutch Caribbean Nature Alliance
RAVON	Reptiles Amphibians and Fish Conservation Netherlands
STENAPA	St. Eustatius National Parks
UVA	University of Amsterdam
SVL	Snout Vent Length
VTL	Vent Tail Length
TL	Total Length

All images and maps by Tim van Wagensveld unless stated otherwise.

Cover photograph: Sub adult *Iguana delicatissima* captured in a garden by Great Estates.

Abstract

The Lesser Antillean Iguana (*Iguana delicatissima*) is native to the Lesser Antilles, a group of islands in the Caribbean Sea. The species is in serious decline, and has been extirpated on islands throughout its geographic range. Therefore *I. delicatissima* now is classified as endangered on the IUCN red list. A better understanding of these animals can help in effectively protecting them. With little known on the behaviour and distribution of the Lesser Antillean iguana on St. Eustatius, I spent 4 months studying this increasingly rare animal. In the search for iguanas approximately 80-84% of the island of St. Eustatius was investigated. To get an idea of the distribution, total population and biology of iguanas, 286 iguanas in total were caught, which includes work done by Thijs van den Burg. Of these iguanas 195 were beaded and 78 were temporarily marked. Nesting sites, hatchling sightings and the distribution of iguanas has been mapped. These maps illustrate fragmentation of the iguana population on St. Eustatius. We have found that both the Boven-and Quill National Parks have very few iguanas, and thus that the majority of iguanas live outside the park boundaries, which is a major cause for concern. Designating new protected areas might be required in order to save the species on St. Eustatius. Further research is needed on nesting behaviour and hatchling dispersion. Furthermore the beading of iguanas must be continued, and continuously monitored. The culling of feral livestock, placement of artificial nests along with a *in situ* head starting/ husbandry program is suggested to bolster the current population of iguanas.

Contents

1. Introduction

The Lesser Antillean iguana (*Iguana delicatissima*) is endemic to the Lesser Antilles, ranging from Anguilla in the north to Martinique at the southern end of the island chain in the Caribbean Sea. It is however rapidly losing ground, due to invasive predators such as the mongoose (*Herpestes javanicus*), habitat loss and hybridization with the Green Iguana (*Iguana iguana*) (Debrot *et al*. 2013; Knapp *et al*. 2014). It now only occurs on the islands of Anguilla, St.-Barthélemy (including the islands of Île Fourchue and Frégate), St. Eustatius, Guadeloupe (including the islands of Basse-Terre, Îles de Petite Terre and La Désirade), Dominica, and Martinique (including Îlet Chancel and Ramier) (Knapp *et al*. 2014) (Figure. 1). The Lesser Antillean Iguana is one of only two species within the *Iguana* genus, the other being the Green Iguana. Unlike *I. delicatissima*, *I. iguana* is widely distributed throughout Central and South America (Knapp *et al*. 2014). Part of the distribution of both iguana species along with other edible species, such as the Red-Footed Tortoise (*Chelonoides carbonaria*) is believed to be attributed to Amerindians during the pre-colonial era (Powell *et al*. 2015). Amerindians are thought to have relocated these animals across the Caribbean to establish food reserves, to ensure food availability on return visits (Knapp *et al*. 2014; Powell *et al*. 2015). More recently established populations of *I. iguana* such as on St. Maarten/St. Martin and on the Puerto Rico Bank can be traced back to the pet trade or due to being imported as food (Powell *et al*. 2015). Historically *I. delicatissima* is associated to the more northern Leeward islands, and *I. iguana* to the southern islands close to mainland South America (Powell *et al*. 2015). The current distribution of both species forms a mosaic within the Lesser Antilles (Powell *et al*. 2015) (Figure. 1). Populations, however, of *I. iguana* may be of natural origin on Montserrat and Saba (Powell & Henderson 2005; Powell *et al*. 2015). Populations of *I. delicatissima* on Anguilla (T. van Wagensveld pers. obs.), Basse-Terre (Pasachnik *et al*. 2006; Vuillaume *et al*. 2015), Grande-Terre (Pasachnik *et al*. 2006), Martinique and St. Barthélemy (Vuillaume *et al*. 2015) now share their home with the Green iguana, resulting in hybrids, effectively giving rise to non-biologically viable populations on certain islands (Knapp *et al*. 2014) (Figure. 1). The Lesser Antillean Iguana is eliminated through introgression, when there are no biological boundaries between it and the Green Iguana (Vuillaume *et al*. 2015). So far *I. delicatissima* has been spared hybridization with *I. iguana* on St. Eustatius, yet is under pressure from cats (Debrot & Boman 2014), dogs (Debrot & Boman 2014), rats (Powell *et al*. 2015) and man (Debrot & Boman 2014). Alteration of natural habitat due to factors such as island development, are also causing the species to lose ground. *I. delicatissima* has now, due to one or multiple factors become extirpated on the islands of Antigua, Barbuda, Les Îles des Saintes, St. Kitts & Nevis, St. Maarten/St. Martin and Marie-Galante. (Fogarty *et al*. 2004; Knapp et al. 2014; Powell *et al*. 2015) (Figure. 1). *I. delicatissima* has experienced a decline of more than 70% of its total population since the arrival of Europeans (Knapp *et al*. 2014). Due to its dwindling numbers, since 2010 it is classified as Endangered on the IUCN Red List (Breuil *et al*. 2010). Were it not for scattered surviving populations on multiple islands, the status listing of 'critically endangered' would necessarily apply (Powell & Henderson 2005). The total population across its geographic range is now estimated at no more than 26,000 individuals (Knapp *et al*. 2014). According to the latest estimates there are thought to be between 275 and 650 animals on St. Eustatius (Fogarty *et al*. 2004). However a minimum viable long term population of 5000 individuals is needed (Debrot *et al*. 2013), and therefore the population's status on St. Eustatius is critical. Only Dominica and Guadeloupe have populations of over 5000 iguanas (Debrot & Boman 2013). St. Eustatius is the only island in the Dutch Caribbean that still supports the Lesser Antillean Iguana. On St. Maarten/St. Martin *I. delicatissima* was extirpated after the introduction of *I. iguana* as recently as 1996 (Breuil 2002). *I. delicatissima* needs proper protection and understanding now more than ever. The other Dutch Caribbean islands have *I. iguana* either as a natural population (Aruba, Bonaire and Curaçao (Buurt 2006); Saba presumed native (Powell & Henderson 2005)) or

introduced (St. Maarten (Breuil 2002)). Due to a lack of information on the biology of *I. delicatissima* (Debrot & Boman 2013), this research thesis on St. Eustatius attempted to address this. Therefore Iguanas were caught in order to measure length, weight and tag them with beads, each with their own unique colour code for long term population monitoring. The daily routine of iguanas was observed in the field, and we also incorporated camera traps to record any day or night activity. According to Knapp *et al*. (2014) nesting occurs over a variable time span depending on the island or conditions in which *I. delicatissima* lives. When nesting occurs on St. Eustatius is still not known. We were, however, able to map nest locations and the distribution of iguanas on St. Eustatius, based on captures and opportunistic sightings. I demonstrate the low nesting availability and fragmentation of the *I. delicatissima* population across the island. The situation is dire for The Lesser Antillean Iguana on St. Eustatius, and extensive measures need to be taken in order to safeguard its existence on the island (Debrot & Boman 2013).

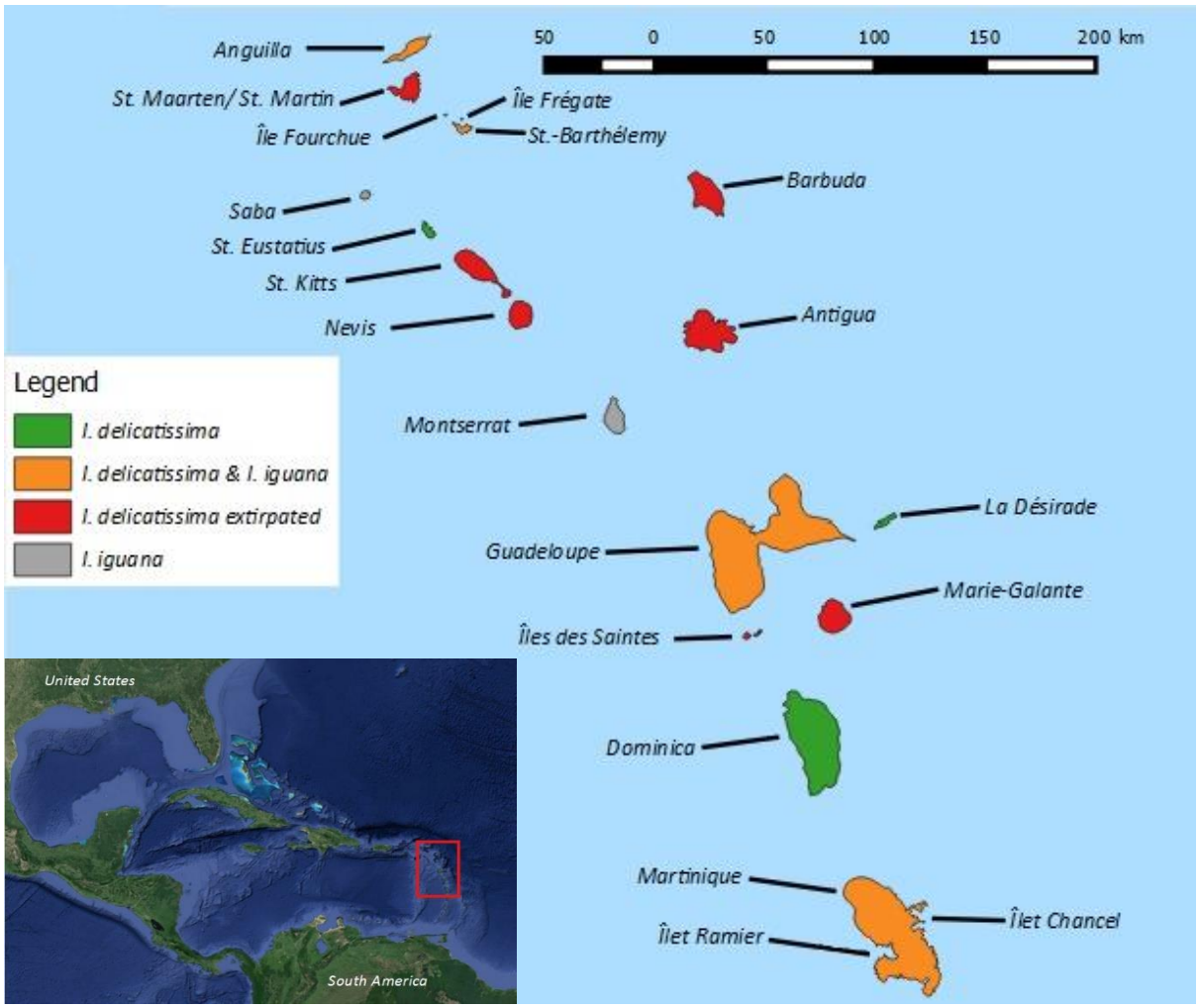

Figure 1. Current distribution of I. delicatissima in the Caribbean. Green: Île Fourchue, Île Frégate, St. Eustatius, La Désirade *,Dominica, Îlet Chancel & Îlet Ramier ; Orange: Anguilla, St.-Barthélemy, Guadeloupe & Martinique; Red: St. Maarten/ St. Martin, Barbuda, St. Kitts, Nevis, Antigua, Les Îles des Saintes & Marie-Galante; Grey: Saba & Montserrat, where I. iguana is presumed native.*

2. Material and Methods

2.1 Study Site

I conducted the research from 22nd July to 23rd November 2015, on St. Eustatius in the Dutch Caribbean. The whole island was investigated where possible. Restrictions applied to certain areas, such as; NuStar's Oil Terminal; naturally inaccessible parts of the island and private property (unless permission was given).

2.2 Species profile – *Iguana delicatissima*

The lesser Antillean Iguana is sexually dimorphic (Figure. 2). Males become larger and heavier than females and turn slate grey as they mature. Females retain much of their green colour as they age, although in some instances large females also turn grey (Figure. 3). Juveniles are emerald green with a brown/black muffled colour towards the extremity of the tail (Figure. 4). The green colour turns darker from the extremities towards the torso as they age (Pasachnik *et al*. 2006). Whitening of the jowls, jaw, throat and snout come with age (Pasachnik *et al*. 2006). Males have obvious white spots on the underside of their hind legs; these are femoral pores, and are much less distinct on females (Figure. 5). Both males and females may exhibit pink cheeks, although this is usually much more clear in males, especially during mating season (Powell *et al*. 2015). At the base of their tails males have two clear hemipenal bulges, whereas the base of a females tail is flat (Figure. 5 & 6). The size of iguanas can vary per island (Pasachnik *et al*. 2006).

Figure. 2: Sexual dimorphism between a male and female I. delicatissima. The female in this case is bright green, grey females are also commonly seen. The male is slate grey, has a much larger head with a prominent hump at the rear of the crown, thicker cheeks, longer spines and more pronounced femoral pores than females. Photograph by Jöran Janse (Stichting RAVON).

Figure. 3: (Left) Green female with bead code RRY. (Right) Grey female with bead code BBP.

Figure. 4: Unmarked juvenile I. delicatissima. Notice the darker colours towards the extremities.

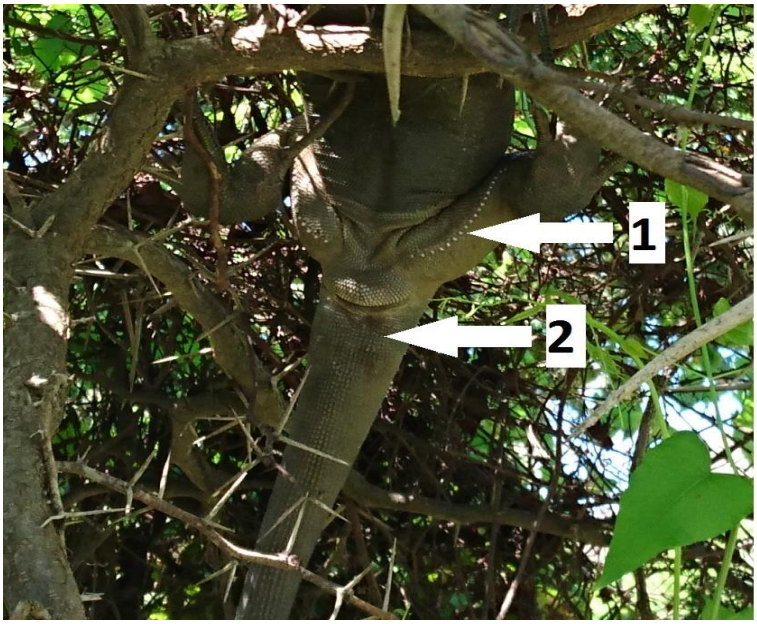

Figure. 5: Male iguana: 1 - Femoral pores. 2 – Hemipenal bulges.

Figure. 6: One of two hemipenes everted in an adult male.

The only other species within the *Iguana* genus is the Green Iguana, which is most easily distinguished from the Lesser Antillean Iguana by its enlarged subtympanic plate (Breuil 2013), and black vertical bars on the tail (Pasachnik *et al*. 2006) (Figure. 7). Both these features are absent in *I. delicatissima*. The *Cyclura* genus, commonly known as Rock Iguanas are found throughout the Bahamas, Greater Antilles and the Virgin Islands in the Lesser Antilles (Lemm *et al*. 2010). Nine species (16 taxa) of Rock Iguana are currently recognised, and they are all endangered (Lemm *et al*. 2010). Rock Iguanas are distinguishable from the *Iguana* genus due to the absence of gular spikes on the dewlap and a dorsal crest which is not continuous (Pasachnik *et al*. 2006) (Figure. 8).

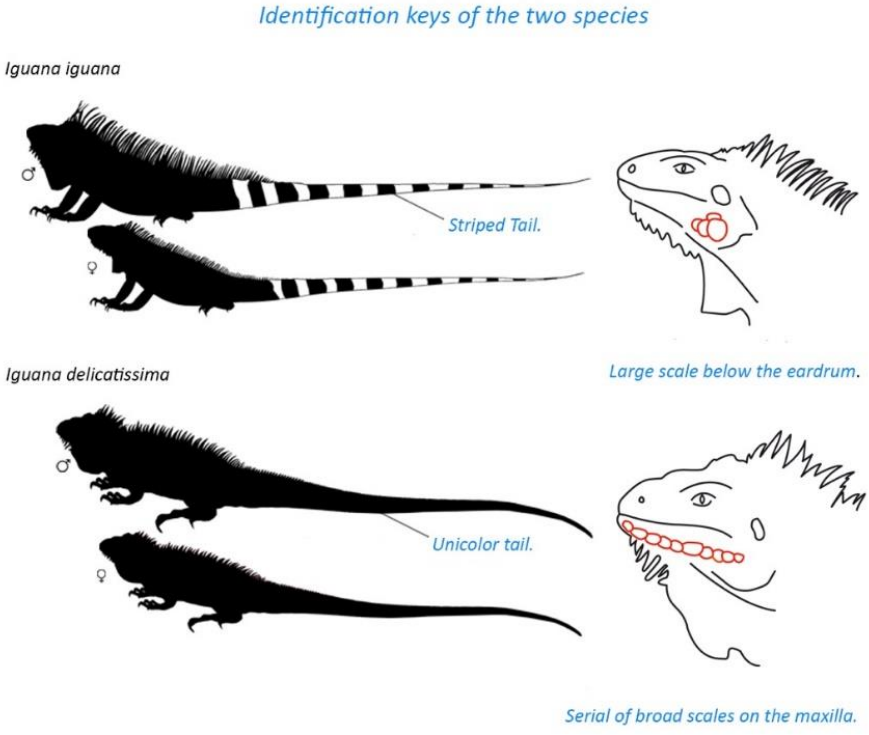

Figure. 7: Identification key of I. iguana and I. delicatissima. Image curtesy of Hannah Madden.

Figure. 8: A Cayman Island Blue Iguana (Cyclura lewisi). Unlike the Lesser Antillean Iguana, gular spikes are absent and It has a non-continuous dorsal crest (Pasachnik et al. 2006). Photograph by Thijs van den Burg.

2.3 Field Methods

Searching for iguanas via transects was not considered a reliable method on St. Eustatius due to the fact that a broad range of vegetation exists, with large parts of the island containing very few to no iguanas. Therefore I took the decision to search the whole island (where possible). An estimated 80-84% of the island was covered in a total of five months and ten days, which includes joint fieldwork from a genetic population study (Thijs van den Burg. MSc student, UVA). For his research blood samples were taken to determine the genetic diversity of the population of *I. delicatissima* on St. Eustatius, and whether a barrier towards gene flow between iguanas in the north and south of the island exists caused by the various infrastructure present (*in press*). The estimated area searched was based on total area measured in QGIS (version: 2.12.1). Iguanas were searched for directly, but also through information obtained from island citizens, the presence of faeces, shed skin, hides and nests. Once spotted, an iguana was caught by using a noose tied to the end of a pole. The iguana was pulled out of a tree once the noose was securely round the animal's neck. Preferably, however, iguanas were caught by hand. All iguanas large enough and with sufficient loose skin by the nuchal crest were given coloured bead tags in between spines (Figure. 9), as described in the beading manual by Binns & Burton (2007).

Figure. 9: Arrow indicating location of beads in nuchal crest. Beads are positioned in between two spines, in excess skin. The bead tag can be no wider than the animal at the position of beading, in order to prevent snagging. (Left) Female with bead code RWB. (Right) Female with bead code BBP.

Each bead code is a unique colour code that allows for visual identification. Figure. 10 illustrates the bead kit with necessary items in order to bead iguanas.

Figure. 10: Complete bead kit. 1: Crimp / Final Cutter tool; 2: Cable Cutters; 3: Seven different types of

coloured Beads - there are 4 packs of each colour; 4: 1 plastic bottle for needle sterilization solution; 5: 80 lb. coated cable, 30 feet per roll; 6: Box with 8 needles (16g & 1in) - 2 boxes per kit; 7: Connector sleeves 7 packs of 25 each. Photograph curtesy of Bart Kluskens.

Beads were available in seven different colours namely: Black (B), Pale blue (P), Yellow (Y), Orange (O), Green (G), Red (R) and White (W). Bead codes are read from the outside in. For example a code with the outer bead as white, middle bead as black and the inner bead (closest to the skin) as blue would be noted as WBP. For a full list of used and available codes, see Appendix A. Beads were placed on iguanas sizing from approximately 26cm Snout-vent length onwards. For some larger iguanas the decision to bead depended on the amount of available skin for piercing. Beading was only performed on (sub) adults, as fast growing juveniles would be affected by the beads, which could result in abnormal growth. Beading juveniles requires a capture/recapture program for which the means were not available at the time of research. Juveniles were marked with a permanent marker (Figure. 11), receiving a letter on the base of their tail or sides (specifically hatchlings, to guarantee the visibility of markings).

Figure. 11: Hatchling temporarily marked as ‘ W’.

After beading an iguana, it was released on the ground and followed as it ran off and disappeared into its hide. That way their hides could be located. Furthermore two old nests and hide burrows were dug up to determine their structure.

2.4 Data Collection and Analysis

To determine the population and distribution of *I.delicatissima* on St. Eustatius, all caught iguanas were either beaded or temporarily marked. A total of 286 were caught, of which 195 were beaded and 78 were marked. The remaining 13 iguanas either escaped or could not be tagged. This was completed in five months and ten days, including work by Thijs van den Burg done in April - May. Approximately 16.8 - 17.7km^2 (80-84%) of the island was covered in a joint search effort.

The following data were collected from captured individuals: snout-vent length (SVL), vent-tail length (VTL), total length (TL), GPS location, parasites, and the presence of abnormalities. Solely recording total length would not be reliable due to many iguanas missing part of their tail. A GPS position was saved of where an individual was caught, or reencountered. This allows their movements to be tracked in the long term. Of each iguana a photo was taken of both sides and the top of the head with the beads. In case the beads break off the heads scale pattern can be consulted in order to determine the original bead code. To gather information about their daily routine, RECONYX camera traps were placed by burrows or in areas where iguanas would frequently pass. Social media was also used, with STENAPA posting messages requesting locals to report iguana sightings so that these could be investigated.

Categorization of adult male/female iguanas was based on the SVL at which they become sexually mature. According to Lemm *et al.* (2010) for males the SVL is 27-28cm, and for females 24-25cm. Sub adult iguanas were categorized as such in order to determine gender from the smallest size possible, which was 18.3cm to 24cm for females and 18.3cm up to 27cm for males. Iguanas with a SVL below 18.3cm were defined as a juvenile. Sub adults for which the sex could not be determined were all larger than 18.3cm and smaller than the indicated sizes for maturity.

All maps were created in QGIS (version 2.12.1). Currently known range and distribution of iguanas is illustrated in green on maps (Figures 25, 27-39) which represent specific parts of St. Eustatius. Range is based on opportunistic (re)sightings or captures for beading.

3. Results

3.1 Iguana delicatissima Profile Data on St. Eustatius

A total of 286 iguanas were caught and an additional 41 were observed, therefore at least 324 iguanas remain (three less due to deaths). The remaining 16-20% of the island that was not investigated contains mostly habitat that is not considered optimal for iguanas, therefore less individuals are expected. Previous population estimates were 300 in 1990, 300 in 1992, 275-650 in 2004 (Fogarty *et al.* 2004) and in 2013 Debrot & Boman (2013) believed it to be at the lower estimate by Fogarty *et al.* (2004). All population estimates illustrate a critical situation on St. Eustatius.

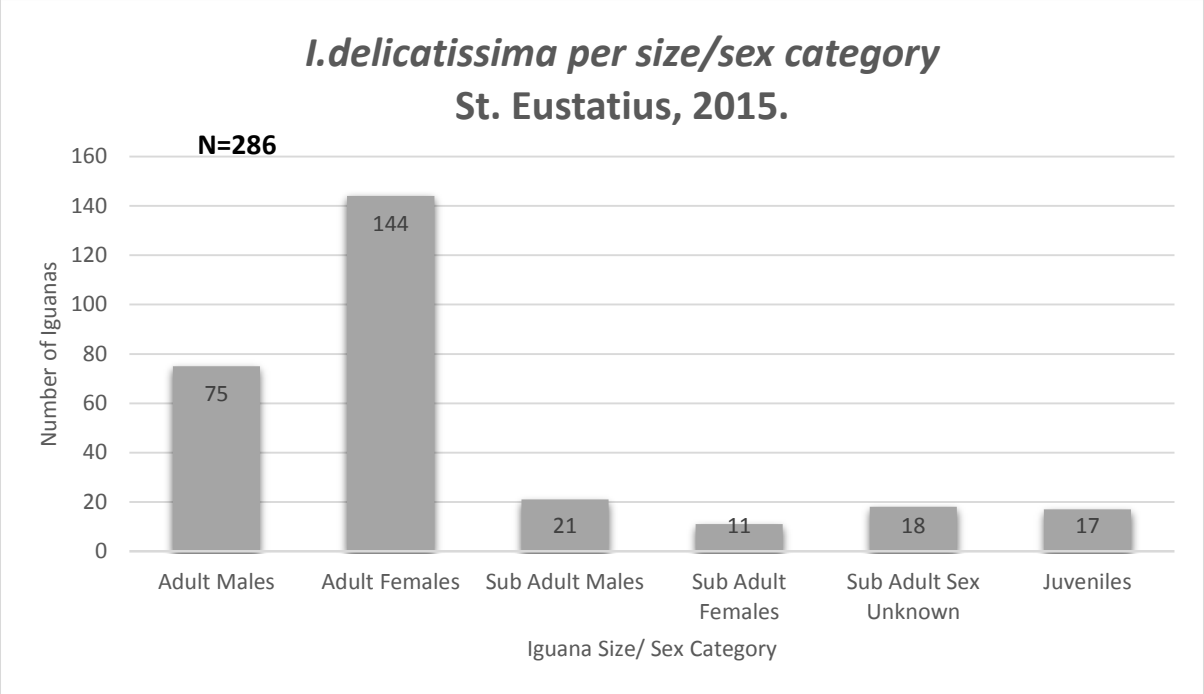

Figure. 12: Total number of captured iguanas categorized per sex and size during fieldwork on St. Eustatius, 2015.

I. delicatissima has a polygynous mating system with a ratio of 1:1 to 1:7 males to females (Alberts 1999). According to Debrot & Boman (2013) there can even be up to 12 females per male. On St. Eustatius we found a ratio of 1:1 to 1:3 (adult males to adult females), with an average of 1:1.9 (Figure. 12). I observed three females with one male on only three different occasions during fieldwork.

Figure. 13 illustrates the range in SVL for The Lesser Antillean Iguanas on St. Eustatius. On St. Eustatius an average SVL of mature male iguanas during our field effort in this study was 32.9cm. The largest total length recorded for a male (not missing part of its tail) was 131cm (n=75). This could have been surpassed by other large individuals had they not been missing part of their tail. For mature females the average SVL found in this study was 30.8cm. The maximum recorded total length for a female was 122.6cm (n=144) (not missing part of tail). The heaviest mature male weighed 2.87kg (n=74), and the heaviest mature female weighed 2.5kg (n=143). The smallest hatchling had a SVL of 7.6cm and a total length of 29.3cm. Table 1. Includes SVL, VTL and TL for the three hatchlings captured.

Table. 1: SVL, VTL and TL of three hatchlings in centimetres. St. Eustatius, 2015.

Hatchling	Captured	SVL	VTL	TL
1	02/10/2015	8.7	21.7	30.4
2	29/10/2015	7.6	21.7	29.3
3	20/11/2015	8.6	22.2	30.8

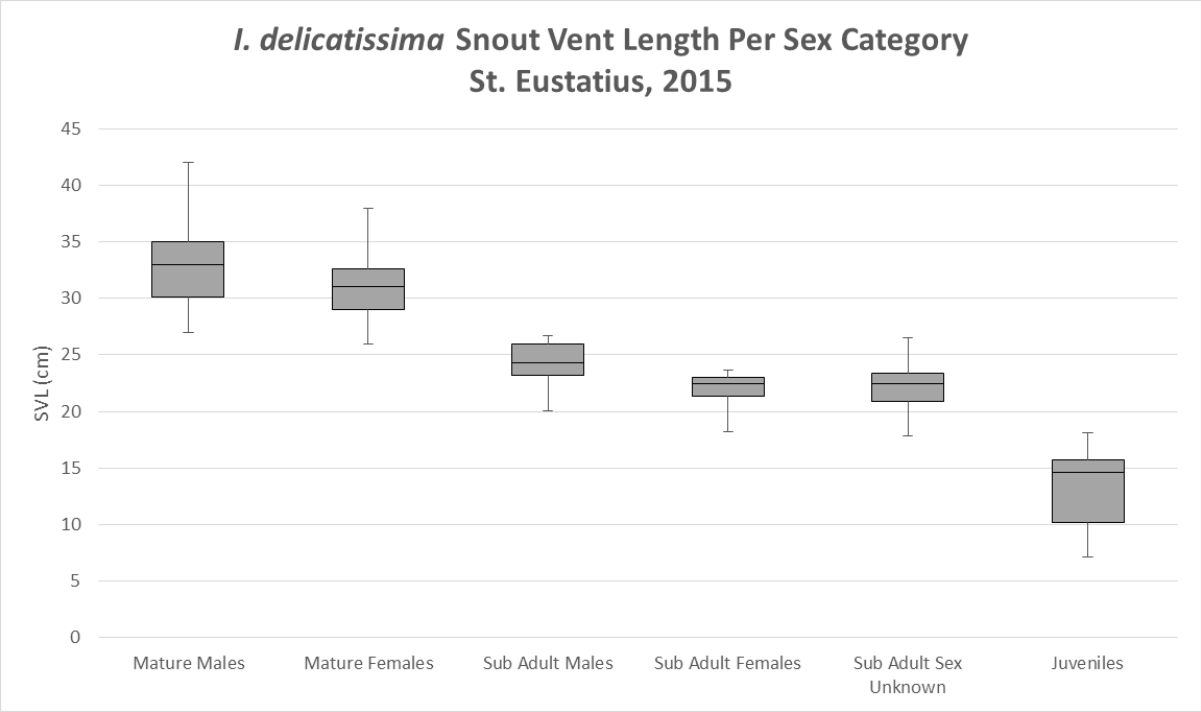

Figure. 13: SVL distribution of captured I. delicatissima per sex category on St. Eustatius, 2015. (Boxplot with median and interquartile range) Mature male max SVL = 42cm; Mature female max SVL = 38cm; Smallest juvenile SVL = 7.6cm.

3.2 Iguana Territory

Based on field observations, males were always accompanied by the same females within their territory. Both males and females were nearly always seen basking in the early hours on the same branch every day. This would be such a routine, that some of the trees used bore scratch marks from climbing iguanas (Figure. 14). These territories were fiercely defended by males against other males. Different males sometimes made use of the same tree to feed (when food was limited), but at different times during the day. It was not until these animals were marked with beads that this could be properly confirmed. This behaviour was only observed in relatively densely populated areas.

Figure. 14: Scratch marks cover this branch due to the long, sharp nails of iguanas moving up it regularly.

3.3 Hide burrows

In order for an iguana to find an adequate site to dig a hide, it should conform to certain standards. Favoured areas contained a large amount of boulders and rocks; many were found under fallen acacia trees, other spiny plants (e.g. *Euphorbia lactea),* or horizontally into sand mounds or cliffs. Areas covered in grass were avoided by iguanas, assuming they prefer areas with light gravel or sand. Two hides were investigated and it was found that these could go as deep as 66cm from a near horizontal angle up to 45˚ angled downwards, after which the tunnel would straighten out horizontally, and continue for approximately 1m, then widened into a small chamber. Iguanas in rocky areas often would make do with naturally provided hides in rocky outcrops or rock piles

(Figure. 15). Hides on flat ground were only dug there if they were covered by rocks or spiny vegetation (Figure. 16). Others were always dug into a mound, hillside or cliff (Figure. 16). On one occasion an iguana was observed running into a hollow Manchineel tree (*Hippomane mancinella)*. On Martinique however, large groups of iguanas could often be found inside hollow trees (A. van Zanten pers. obs.).

Figure. 15: Iguanas hiding in rock crevices. Iguanas return to the same hide each time they need to use it.

Figure. 16: (Left) Hide dug into a mound of sand. (Right) Hide is under a fallen Acacia tree.

It was found that each iguana had a ‘ private’ hide that they would run to. Multiple green iguanas, on the other hand can share the same burrow (A. Debrot. pers. comm.). Camera trap images also confirmed that the same iguana would use a single hide, and that it was not shared by other iguanas. Burrows were never far from where the individual was resting or feeding. In general, basking or feeding was usually no more than 25-30m away from a burrow (observed in nearly every individual captured, also re-sightings). There were only a couple of exceptions where iguanas would cover greater distances, the furthest being approximately 80m. An iguana was never documented sleeping in a hide at night; they were only documented being used during midday (usually between 13:00 – 15:00) when the sun was at its hottest (Figure. 17), or when frightened. Iguanas would stay in their burrow between thirty minutes to an hour and a half, and then leave again after checking whether it was safe to come out.

Figure. 17: Camera trap image near Lampeweg, St. Eustatius, of a male iguana with bead code (YB) that is about to enter its hide (center bottom of image). Time: 13:15; temperature: 42˚C; 02-09-2015.

Iguanas would dig during midday, which was caught on camera trap images and seen during personal observations. A new burrow would be made in multiple stints spread out over a number of days. Maintenance of burrows was also only observed being done during midday, this being contrary to what was expected, being the hottest part of the day.

Iguana hides would often be visited at night by black rats (*Rattus rattus*) (B. Kluskens pers. comm.) (Figure. 18) and land crabs (*Gecarcinus ruricola*). Cats were also a common sight on camera traps, by gardens as well as in the bush peering into burrows.

Figure. 18: Camera trap image of a black rat leaving the same burrow on St. Eustatius as seen in Figure. 17. Time: 19:29; 02-09-2015.

3.4 Nesting

I found a total of four confirmed nest sites, of which none were actively being used at the time of research (Figure. 19). Other studies also found very few nests (see: Debrot & Boman (2013); Debrot & Boman (2014)). Two nests were in a garden of a private residence, and two were located next to each other behind Little Mountain (Figure. 19). At three nest locations desiccated eggs were found on the surface (Figures. 20 & 21). The amount of eggs found per nest were: 10, 4 and 1. I was told by the residents at the Quill nest site (Figure.19), that they see adults nesting there each year, and that hatchlings emerge in October.

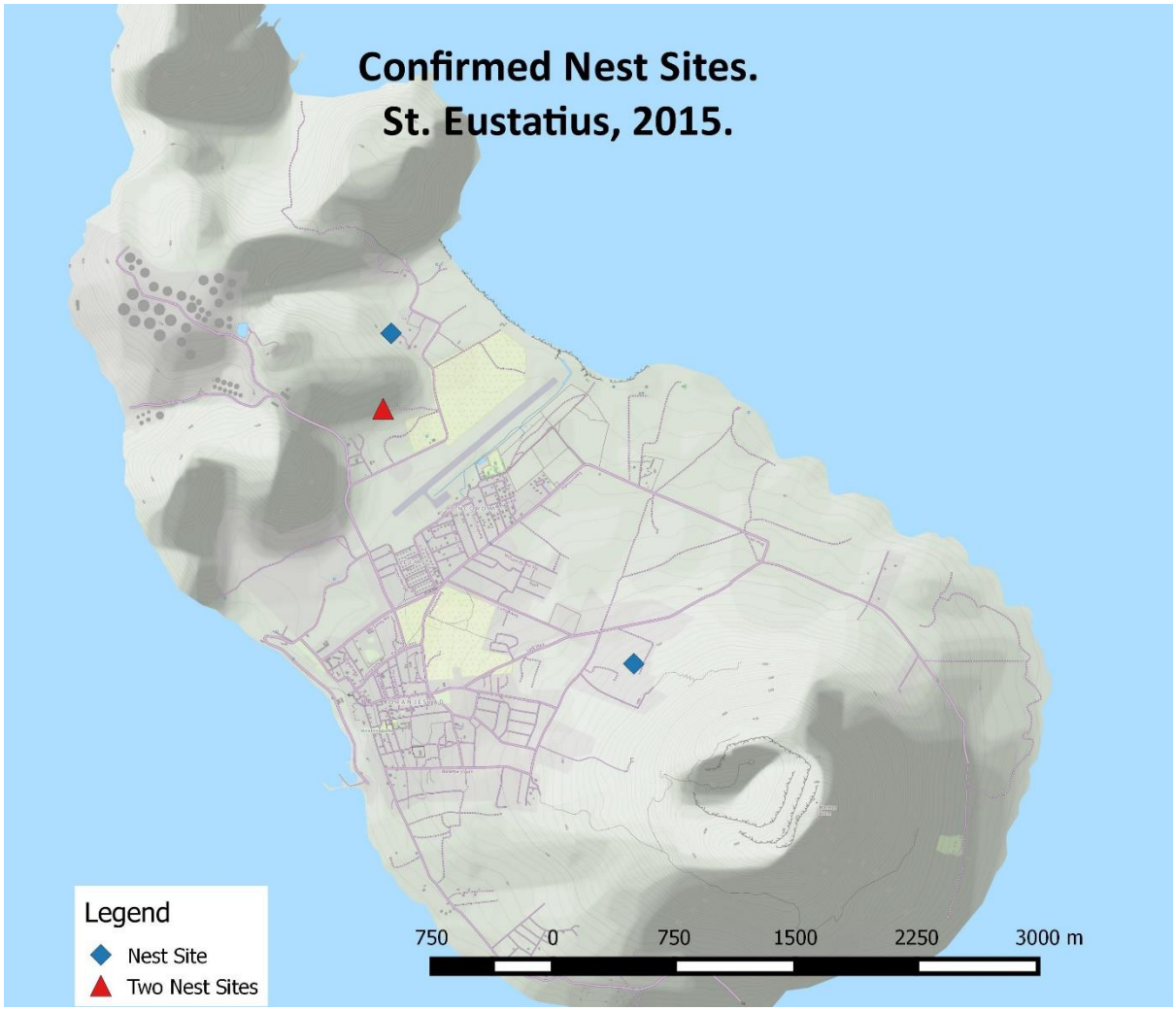

Figure. 19: Confirmed nesting sites found on St. Eustatius, 2015. Both single nests were in a garden. The two nest sites next to one another were located behind Little Mountain.

Nest sites could differ from being predominantly sandy to containing gravel. A core was taken from each nest. The top 20-30cm of the core was dry, drained loose sand. Deeper parts of the core showed an increase in moisture. Depending on the permeability of egg shells and the microclimate in which they are laid, this will have to be done at a specific depth to prevent egg desiccation (Ackerman 1991). All nests were subject to only minimal shading during the day and were all found in flat areas.

Figure. 20: Nest site found behind Little Mountain, St. Eustatius (August, 2015) with 10 eggs (four indicated with arrows) lying on the surface, most likely a clutch from the previous year, due to the time of year that they were found. The substrate/site was a mix of light gravel with fine sand, surrounded by low sparse vegetation.

Figure. 21: A single desiccated egg found at the most northern nest site (Figure. 19). Photograph by Bart Kluskens.

Nesting sites are in high demand and suitable habitat is under increasing pressure. The invasive vine *Antigonon leptopus,* native to Mexico and otherwise known as Corallita, is spreading on the island and smothers native vegetation. Degraded areas are especially prone to Corallita growth, mainly caused by grazing goats (Debrot & Boman 2013). Feral goat numbers are estimated at just under 3000 individuals (Debrot *et al*. 2015). No grazers have been documented eating Corallita, thus adding to the problem. Huge areas can be completely covered in Corallita which forms dense mats. According to the latest estimate, 33% of St. Eustatius is covered in Corallita (Berkowitz 2014). Three years earlier, in 2011, 20% of the island was covered (Burk & DiTomasso. 2011), thus the latest estimate illustrates its rapid expansion. The few nesting sites that remain are at great risk of being smothered by the rapid expansion of Corallita (Debrot & Boman 2013).

An attempt was made by STENAPA to create artificial nest boxes to increase nesting availability. In the absence of any prior scientific knowledge on the Lesser Antillean Iguana's nesting behaviour, nest boxes were based on work by Goodman *et al*. (2005) with the Cayman Island Blue iguana (*Cyclura lewisi*). None of the six placed nest boxes contained any eggs nor signs of use by iguanas. These nest boxes had a horizontal entrance/exit, and were probably too small to accommodate a fully grown female. Old dug up nests were seen to have been dug by iguanas in a much steeper/vertical fashion, not horizontal.

3.4 Hatchling and Juvenile Iguanas

We found the first hatchling after two months of searching in October. Part of the former vessel connection to the yolk sac/allantois still remained under the belly, indicating that this individual was approximately three to four days old (Figure. 22). In total eight hatchlings, of which three were caught (Table. 1), were documented at six different locations (Figure. 23). Seven were found in October and one in November. These findings were all within the rainy season (end of August/beginning September through November/December 2015). This implies that there is a synchronous reproductive season on St. Eustatius, similar to other islands such as Petite-Terre and La Désirade (Knapp *et al*. 2014).The vegetation noticeably changes, becoming more lush and greener than in the dry season. It is this lush vegetation upon which the juveniles depend in order to blend in and thus ensure protection from predators.

Figure. 22: A hatchling Iguana approximately three to four days old. A small piece of former vessel connection to the yolk sac/allantois still remains on this young individual. Photograph by Thijs van den Burg.

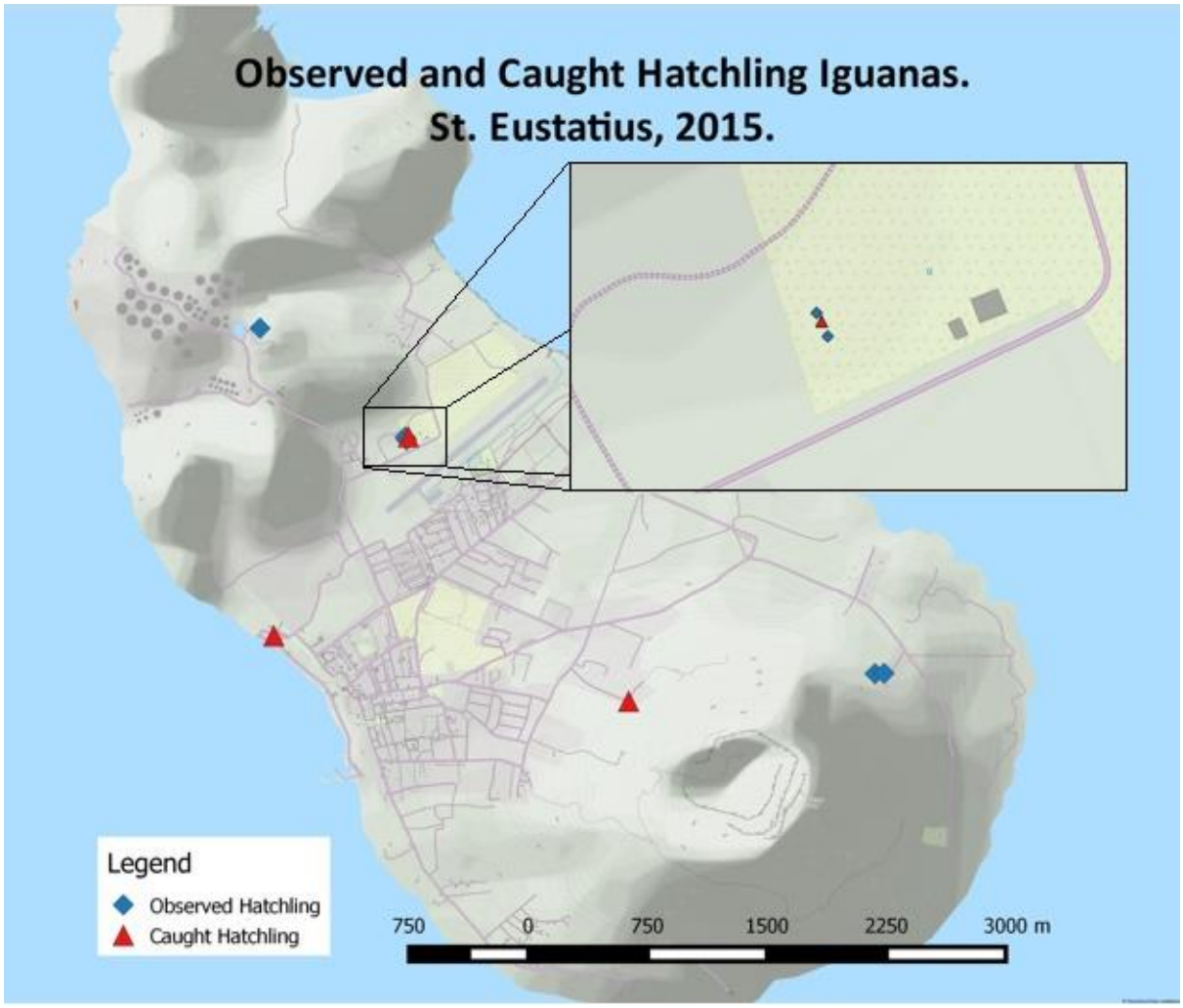

Figure. 23: Location of observed and caught hatchlings on St. Eustatius, October-November, 2015.

Six hatchlings were found on or near the ground hidden under low yet very dense bush, as also noted by Knapp *et al*. (2014). When threatened, hatchlings would shoot into or under low vegetation covering the ground, and remain very still.

A small privately owned, fenced off area close to the airport, on the cultuurvlakte (central plains), was found to have one of the highest iguana densities on the island (Figure. 23 Insert). All life stages were represented here, from hatchlings to fully grown adults. On multiple occasions I observed that adults (including large males) were seen basking in the same tree a branch away from juveniles and (male) sub adults. This might indicate that there is no direct need for juveniles to disperse as long as food and shelter are plentiful. Males reaching sexual maturity, however, will not be tolerated by established males, as they then directly compete for females.

Juveniles of approximately one to three years old would suddenly appear from low lying vegetation, and in an almost synchronized fashion climb up the same tree (usually *Vachellia sp*.) every day. This occurred between 09:00am and 10:00am. For the remainder of the day juveniles would stay in close proximity to one another, feeding and basking. On average juveniles would alternate four times per hour between basking in the sun and hiding in the shade. Fully grown adults would stay in the sun or shade for an extended duration, which could last for hours.

3.5 Optimal Habitat

According to Pasachnik *et al*. (2002) and Alberts (1999), *I.delicatissima* can thrive in a broad range of environments from mangroves, xeric scrub, dry scrub woodland, humid forest (lower altitude portions of transitional rainforest) and dry rocky shrub lands. They are also regularly seen in dog-free lush gardens. With two national parks and plenty of bush and forests on St. Eustatius one would expect sufficient suitable habitat to sustain large populations of iguanas (For a map of St. Eustatius with National Parks see: Appendix B). This, however, is a skewed image, as many areas appear void of any iguana life (Figure. 26). Both national parks apparently harbour surprisingly few iguanas, contrary to what might be expected. This also applies to much of the bush and forest elsewhere on the island that is homogeneous in nature. This homogeneous forest/bush offers little variation in food, cover, vegetation height and basking availability (Figure. 24). Seeing an iguana deep in one of the forests was a rare sight. They could, however, be found on forest edges along roadsides, or by clearings (Figure. 25). Usually iguanas were discovered between two and four meters, up to +/- ten meters in the vegetation. A clear preference for discontinuity in vegetation was found. Iguanas seemed to avoid dense forest, and prefer pockets or patches of forest located next to open areas. Many of the forests were lacking undergrowth due to grazers, mainly goats (Debrot *et al*. 2015). Goats were found in large numbers across the whole island. Feral goats are the most numerous grazers on St. Eustatius and have a deleterious effect on the natural biodiversity (Debrot *et al*. 2015). Feral chickens, affectionately known by locals as garden or jungle fowl, are also recognised as having a negative impact on biodiversity throughout the Caribbean (Debrot *et al*. 2015). Chickens were most numerous in and around the Quill (T. van Wagensveld pers. obs.).

Figure. 24: Non optimal habitat for The Lesser Antillean Iguana. (Left) The plains by the English Quarter, offer little in shelter and food for iguanas. (Right) Forest on the West side of Signal Hill, where barely any undergrowth remains, and no iguanas were found. St. Eustatius, 2015.

Figure. 25: Optimal habitat for The Lesser Antillean Iguana. (Left) A Large gorge by Whitewall, strewn with boulders lined on both sides by a strip of forest. (Right) By Little Mountain, the forest edge next to an open area. St. Eustatius, 2015.

3.6 Distribution

Figures 27, 29 – 41 Illustrate in green, areas known to be (part) iguana territory based on opportunistic (re)sightings and captures, and also give an indication of population distribution and fragmentation.

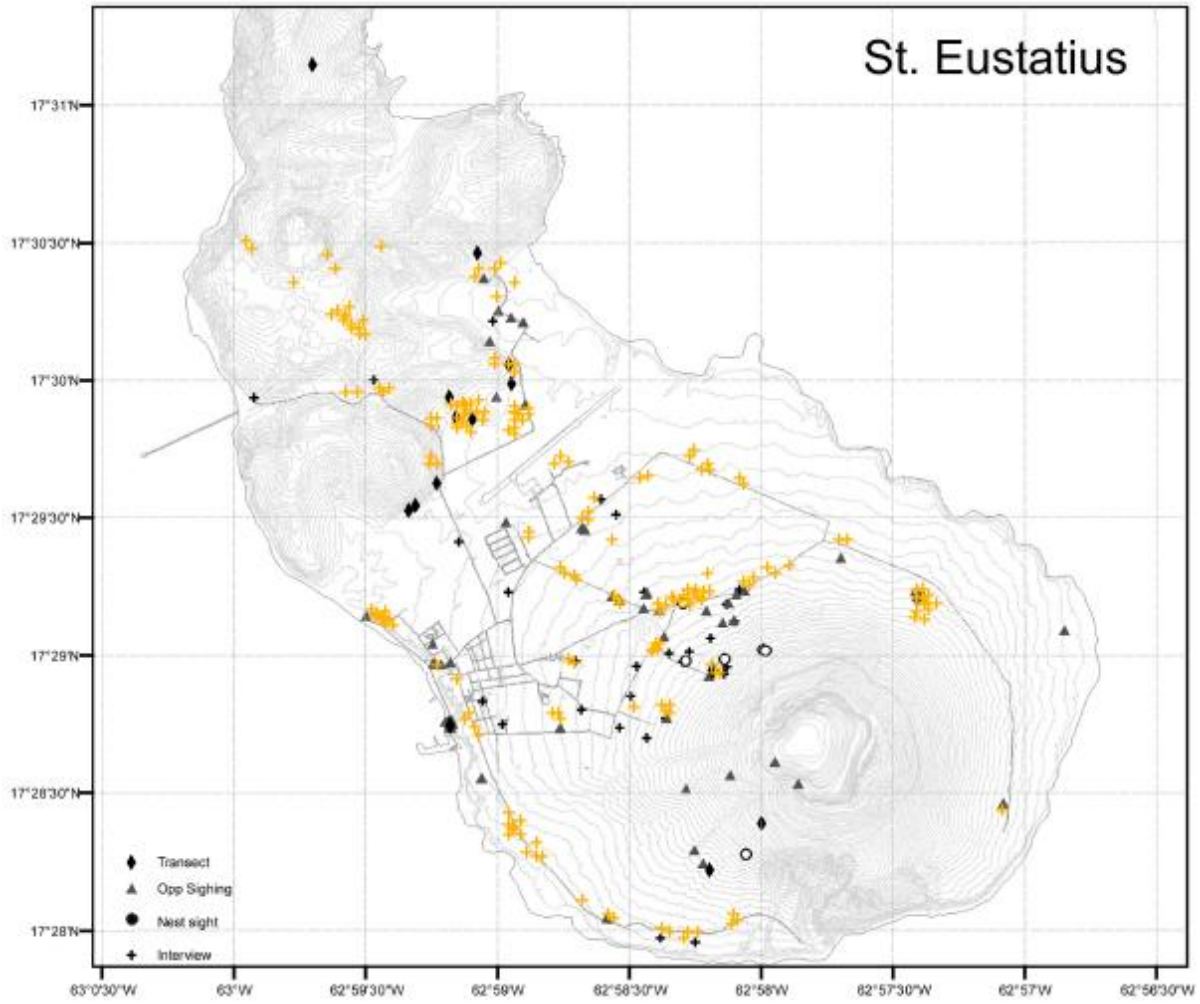

Figure. 26: Black triangles= sightings by Debrot & Boman (2013), yellow = sightings in 2015 on St. Eustatius. Map represents 266 of the captured iguanas in 2015. Source: Stichting RAVON.

An extensive search (~30 hours) was conducted in Boven National Park which comprises three mountains; Bergje, Gilboa Hill and Boven. NuStar's oil terminal bordering Boven National Park was also investigated, however due to safety/clearance company policies it was not possible to explore the entire terminal property. Boven National Park has large patches of forest, broken up by extensive grass cover on south facing hills and ridges. The forests have few low growing shrubs under the tree canopies, and are rather uniform in height and composition. Lack of undergrowth is a consequence of overgrazing by feral livestock (Debrot *et al*. 2015). Within these forests no signs of iguanas were found (Figure. 27). Only one (female) iguana was found deep within a forest on a trail leading up to Bergje. In this area, large boulders were scattered on the forest floor and provided cover for a single (found) burrow. This corroborates with the findings by Debrot *et al*. (2013) and Debrot & Boman (2013), where after a search time of 28 hours within Boven National Park only two iguanas were found. All other iguanas were close to or within national park boundaries, particularly by NuStar. Either sides of the stone deposits on a large slope by the eastern border of NuStar' s property offer excellent habitat (see area marked in red, Figure. 28). Large rocks and shrubs line the

forest edge. A hatchling and adult female were found close to the top of the ridge. The area requires a more thorough search, but is hard to reach.

Figure. 27: Boven National Park. St. Eustatius, 2015. No iguanas were found except on the southern borders of the park.

Figure. 28: The indicated area in red, on a rocky slope directly adjacent to NuStar requires a more extensive search for iguanas as it contains excellent habitat, and one hatchling and adult female were seen here. St. Eustatius, 2015.

The area on the most northern point of NuStar' s terminal is home to an unknown number of iguanas, potentially a relatively large population. Here the cliffs are steep, located above the Caribbean Sea, and offer excellent iguana habitat. This area is littered with boulders, the trees are spread out and do not form a complete canopy cover. Where the remainder of NuStar's fence line borders dense forest, however, no evidence of iguanas was found. In a small patch of forest just outside NuStar's fence, by the main entrance, a small population of iguanas exists. In this area tree cover is less dense, and there is ample cover under boulders or prickly bush for iguanas to hide. Within NuStar's terrain, many areas of patchy forest/bush offer excellent habitat for iguanas. Some are fed by NuStar employees and are now conditioned to this. 18 iguanas were beaded on the

NuStar terrain (14th & 21st October, 2015), and more were observed. More iguanas live within NuStar's grounds than initially expected. NuStar was visited twice, with a total search time of approximately 14 hours (Figure. 29).

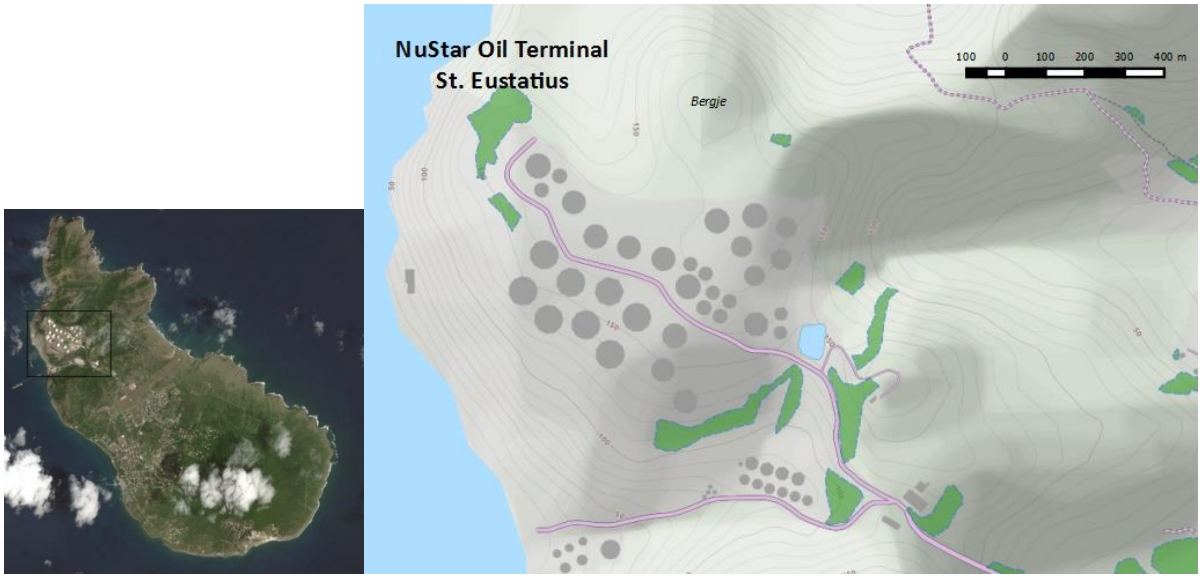

Figure. 29: NuStar Oil Terminal. St. Eustatius, 2015.

Much of the terrain within the national park, especially the trail leading to Boven, has very little suitable habitat to sustain a large population. Much of the terrain is covered in grass, with only a few different shrub species clumped in certain areas facing the south/ south-east. Hillsides facing other directions comprise mostly dense forest. Patches of vegetation in the valley next to Venus bay provide a suitable habitat, although no iguanas were found there. This might be a good site to relocate unwanted iguanas caught in residents' gardens. Perhaps suitable habitat deep within the national park is now too big a hurdle for established iguana populations elsewhere outside or on the borders of the national park, as substantial terrain would need to be crossed to get there. A few iguanas reside by the initial trail leading into Boven National Park (Figure. 30).

Figure. 30: Zeelandia Bay and initial trail leading into Boven National Park. St. Eustatius, 2015.

Next to the NuStar terminal lies signal hill (~40 hours total search time), which is covered in boulders, has many large *Cereus hexagonus* and offers plenty of discontinuity in vegetation. The bottom half of Signal Hill harbours what seems to be a relatively large population of iguanas, also found by Debrot & Boman (2013). Less iguanas were observed, with increasing elevation up Signal hill. The top of Signal Hill and the entire area behind it showed no signs of iguanas. To the east lies Little Mountain, where a small population (six to seven iguanas) was discovered (mainly on the south side). The area between Little Mountain and the adjacent car dump to the west had one of the more densely populated areas. Calabash trees (*Crescentia cujete*) define this area, complemented by prickly bush under which most iguanas in this area have their hides. Just south of Little Mountain is a fenced off area (2.5 acres of private property), that has at least 18 iguanas within it, and possibly more unaccounted for juveniles (Figure. 31). This is the highest density of iguanas that I found.

Figure. 31: Signal Hill and Little Mountain. St. Eustatius, 2015.

A small group of four to five iguanas lives at the edge of the beach by Zeelandia Bay, in sea grape (*Coccoloba ufivera*) trees surrounded by dense prickly bush. Areas with only sea grape trees and, no other vegetation adjacent did not show evidence of iguanas, as could be seen in the entire island. A little more inland a few more small scattered pockets of iguanas are present (Figure. 30). Iguanas living close to the beach could regularly be observed sneezing in order to expel salt, whereas iguanas inland were never observed demonstrating this behaviour. This sneezing behaviour ensures that excess potassium, sodium and chloride are excreted (Hazard 2004). The iguanas at Crooks Castle and Zeelandia Bay show this behaviour very often. In particular the iguanas by Crooks Castle were seen close to the waterline on a few occasions (Figure. 32).

Figure. 32: Harbour Area, including Crooks Castle. *St. Eustatius, 2015.*

When there was continuity in homogeneous vegetation, iguanas were not to be found. The greater part of the plains and forests/bush along the coastline from the airport towards Corre Corre Bay hold either very small densities or no iguanas at all (total search time ~40 hours) (Figures. 26, 33 - 35). The old sugar mill has a group of five – seven iguanas that live amongst the ruins. The entire area surrounding the old sugar mill was searched, with no signs of iguanas. This might be one of many small iguana populations, with little or no access to other groups of iguanas (Figure. 33). No iguanas were found in the area by the English Quarter, which was said to hold a good, but declining population two decades ago (Reichling 2000) (Figure. 33).

Figure. 33: English Quarter and the old sugar mill. St. Eustatius, 2015.

Along the road leading towards the botanical garden there are a few sporadic areas that have iguanas. At the top behind Knippenga Estate there are three small populations known (Figure. 34). A large pile of wooden boards and wooden beams lie here. Welcomed by the iguanas they seem to use it as a shelter. Iguanas have been seen to happily use large (high) piles of (manmade) debris as a shelter site all over the island. Probing deeper into the forests behind Knippenga, no more signs of iguanas were found. Another small group, where a hatchling was even found, resides just below the highest house. At the bottom of Knippenga in an area covered by *Guilandina bonduc* and sporadic tree cover, supports a couple of iguanas. As soon as the bush thickens, no more signs of iguanas are to be found (total search time~15 hours) (Figure. 34).

Figure. 34: Knippenga Estate and the Corre Corre Bay area. St. Eustatius, 2015.

Despite an intensive search (~30 hours) of the Miriam C. Schmidt Botanical Gardens, and the surrounding area, only two iguanas were observed in the Botanical Gardens (Figure. 35).

Figure. 35: Miriam C. Schmidt Botanical Garden. St. Eustatius, 2015.

On the southeast side of the island by Whitewall, iguanas live by the main road (Figures. 26, 36 & 37). On more than one occasion iguanas were seen here basking on the relatively quiet road. The main forests between the road and the beach have very few to no iguanas. The iguanas in this area are mainly concentrated around the road, and a few live in gullies and ravines that are perpendicular to the beach. These proved good spots for finding iguanas all over the island, and should always be extensively investigated.

Figure. 36: Route 1 to Whitewall. St. Eustatius, 2015.

Figure. 37: Whitewall and Battery de Windt. St. Eustatius, 2015.

The Quill National Park showed no signs of iguanas including skin and/or faeces, either on the upper slopes or inside the crater (Figure. 38), likewise Debrot *et al*. (2013); Fogarty *et al.* (2004) and Reichling (2000) found no iguanas in the crater.

Figure. 38: The Quill area on a larger scale. St. Eustatius, 2015.

The highest found individual (female) was just outside the Quill National Park, above Whitewall at an elevation of 287m. No iguanas were found at higher elevations which corroborates with Alberts (1999) and Pasachnik *et al*. (2006), where 300m is the highest documented elevation at which iguanas were found. One iguana has however been observed on a tree trunk within the crater, the crater rim is 400m at the lowest point (H. Madden pers. comm.). On Dominica, iguanas have been seen at elevations of up to 1000m (Breuil *et al*. 2010; Knapp *et al*. 2014). The forests on/in the Quill can be very dense, and like with all other dense forest on the island, iguanas were either not present or were present in very low densities. The lower part of the slope maintains a population by Island Estates (Figure. 39). Here lush gardens provide a variety of food and are frequently visited by resident iguanas from garden edges, provided no dogs are present.

Figure. 39: The Island Estates on the lower slopes of the Quill. St. Eustatius, 2015.

In Oranjestad (Figures. 26, 32, 40 & 41) very few iguanas were present. On the outskirts however they could be seen in gardens with adequate resources for iguanas. Smoke Alley (Search time ~ 10 hours) was said to have one of the highest iguana densities on the island by Fogarty *et al*. (2004). Although some individuals were found here (five), it is most probably not as densely populated as it was over a decade ago. There are however, four areas in Smoke Alley that have a number of hides and possibly nests. Not all seemed to be in use, only one iguana was observed running into a hide, and one other iguana into a hollow Manchineel tree. The cliff below the Kings Well Resort, had dozens of hides and possibly nesting burrows, and appears to be a promising habitat (Search time ~ 2 hours). Three adults and a hatchling were caught here. The owners of Kings Well Resort indicate that there are about 12 adults on their property, and this is considered likely given the burrows discovered in the area. Moving down the waterfront, the entire cliff face still requires extensive searching up to the Tompi Hill trail (behind STENAPA's Visitors Centre; Figure. 32), which is home to at least five individuals. Beyond the harbour the only area to still hold a small group of iguanas, is Crooks Castle (Figure. 32). At least six or seven iguanas remain in this area.

Figure. 40: Smoke Alley and Oranjestad. St. Eustatius, 2015.

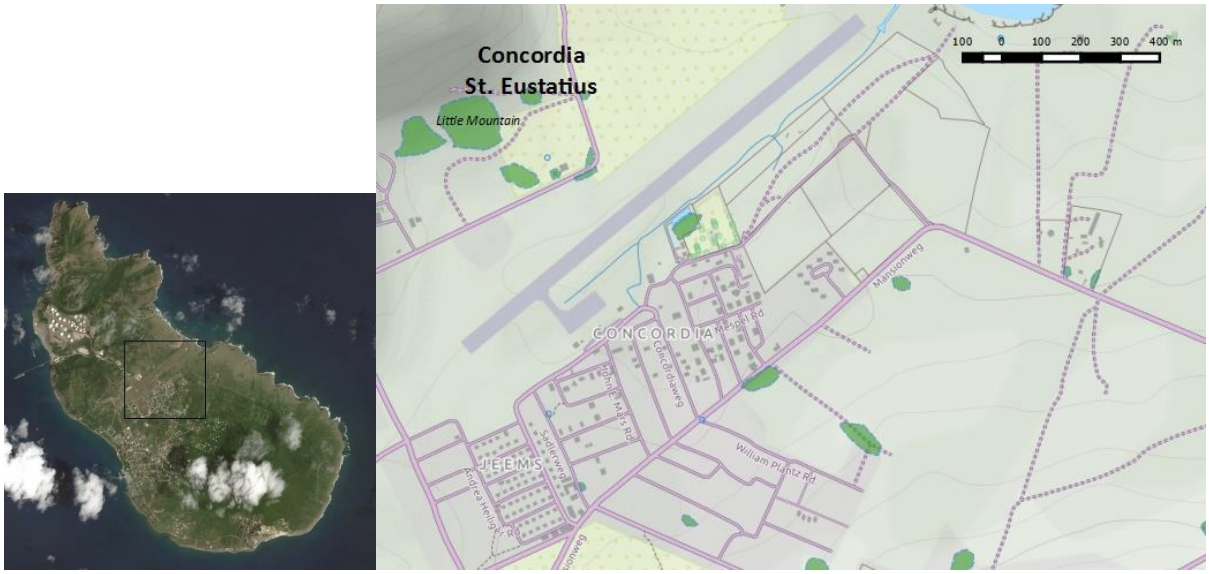

Figure. 41: Concordia and F.D. Roosevelt Airport. St. Eustatius, 2015.

A few species of plant were preferred as cover among iguanas in different life stages. Young individuals were mainly found in bright green bushes, not far from the ground. Sub adults would occupy the broadest range of vegetation, and adults seemed to be fond of *Euphorbia lactea and Pandanus spp.* (Appendix C). *Euphorbia lactea and Pandanus spp.* in particular were often used as a central point by iguanas. Iguanas would sleep deep inside these plants at night and fall back to them after feeding elsewhere (in close proximity), or when they felt threatened.

3.7 Feeding Habits

The Lesser Antillean Iguana is herbivorous and feeds on a wide variety of plants (Alberts 1999; Durrell Wildlife 2001; Knapp *et al*. 2014; Powell *et al*. 2015) (Appendix C), including highly poisonous plants that cannot be eaten by mammals or birds such as Manchineel (*H. mancinella)* (Alberts 1999) (Figures. 42 & 43). In general, feeding takes place in the morning (Alberts 1999; Knapp *et al*. 2014), which was confirmed by field observations. After basking and warming up in the morning sun, feeding was usually between 10:30 and 15:00, with intensity decreasing as the day progressed. The highest feeding intensity was seen at approximately 11:00 in the morning. Only on two occasions were iguanas seen eating late in the afternoon. Adult iguanas would on occasion not eat for an entire day. *Iguana delicatissima* is reported to shift from folivory in the dry season to folivory and frugivory in the wet season (Durrell Wildlife 2001; Knapp *et al*. 2014). This was observed as the dry season shifted to the wet season. Many animals caught for beading in the wet season were found with dried up fruit juices on their faces from feeding on cherries or other fruits. Seeds became increasingly prevalent in faeces. Iguanas disperse seeds and can thus be vital for certain plant species (Breuil *et al*. 2010; Durrel Wildlife 2001; Knapp *et al*. 2014). Iguanas are the largest native herbivore on St. Eustatius. In particular species such as the Manchineel tree depend on iguanas, as no other animal can tolerate its toxicity (Knapp *et al.* 2014). Food is currently not considered a limiting factor on St. Eustatius for iguanas (Debrot *et al*. 2013), even though Corallita is smothering parts of the island and potentially outcompeting native species (Burk & DiTomasso. 2011).

Figure. 42: Female I. delicatissima eating H. mancinella apples. Crooks castle, St. Eustatius, 2015.

Figure. 43: Hippomane mancinella apple partly eaten by an I. delicatissima. Iguanas living under or close to Manchineel trees frequently eat the fruits lying on the ground. St. Eustatius, 2015.

Juveniles had a clear preference for young sugar apple (*Annona squamosa*) leaves. They would eat up to 25 young leaves in one sitting, moving along a branch. A small hatchling was observed eating the fruit (both green and ripe) of *Guilandina bonduc* on a single occasion.

After heavy rain, iguanas lap up water collected on leaves. This behaviour, however, was rarely observed (two occasions), as iguanas would often retreat into thicker bush during showers. Iguanas possibly get a large portion of moisture from the leaves and fruit that they eat, particularly in the dry season.

3.8 Disease and Abnormalities

69.2% of all caught iguanas harboured mites (unknown species) somewhere on their body, with 92% of those being on or around their face. However, most iguanas found in close proximity to the sea had no mites on their bodies. Mites, despite their small size (0.5-1mm) can easily be distinguished on the skin of iguanas as they are bright red. They usually live in between folds of skin and larger scales (Lemm *et al*. 2010) (Figure. 44). Durden *et al*. (2015) found ticks, specifically *Amblyomma antillorum,* on 517 of 1,149 iguanas (45%) on Dominica. None of the captured iguanas on St. Eustatius, however, had ticks.

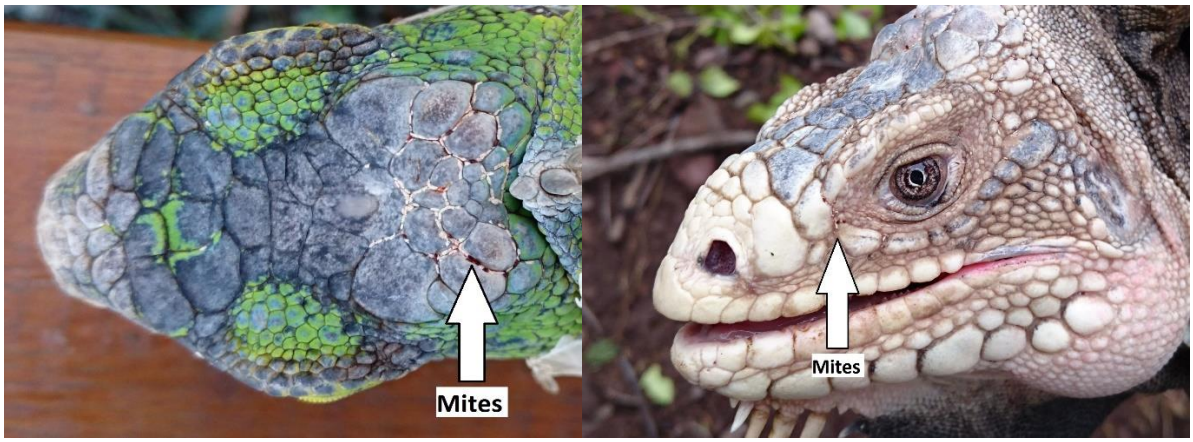

Figure. 44: Mites on the crown and side of the head.

Twenty nine out of 286 captured iguanas were missing part of their body such as toes, legs, spines and tail. In many cases most of these missing parts were most likely caused by cats or dogs. Two iguanas had abnormalities: Bead code YYB had extra limbs growing on both its front legs. Both limbs

were non-functional and not fully developed (Figure. 45). Bead code OWB had an apparently fully developed 'normal' tail, however it lacked bones. The tail was therefore extremely flexible, beyond what was normal for iguanas.

Figure. 45: Male with bead code YYB, has a non-functional appendage growing from both front legs. Photograph by Thijs van den Burg.

St. Eustatius has so far been spared a disease affecting *I.delicatissima* on a few other islands. It is possibly caused by the actinobacterium *Devriesea agamarum* (Knapp *et al*. 2014 & references therein). On St.-Barthélemy some iguanas carry this dilapidating disease whereby skin lesions occur (Knapp *et al*. 2014). On Martinique (A. van Zanten pers. comm.) and on Anguilla (T. van Wagensveld pers. obs.) iguanas have been observed with similar symptoms. Iguanas on Anguilla, are currently under investigation by the Anguilla National Trust to determine the cause. Further investigation into these diseases and management thereof, is required in order to prevent further spreading to other islands, including St. Eustatius, where no similar cases are reported.

3.9 Hybridization

Four islands that support *I. delicatissima* have been invaded by *I. iguana*, with devastating consequences for native iguana populations due to hybridization. Fortunately, the Green Iguana is still absent from St. Eustatius. The last 'genetically pure' populations, probably now only occur on St. Barthélemy, Dominica, La Désirade, La Petite Terre and St. Eustatius (Powell *et al*. 2015). Green Iguanas have been known to naturally spread to other islands via vegetation rafts (Powell *et al*. 2015), and due to anthropogenic causes (Vuillaume *et al*. 2015). It is critical that Green Iguanas do not enter St. Eustatius or any of the other islands that are still free from them.

3.10 Mortality

Due to its endangered status, every death of *I.delicatissima* on St. Eustatius should be documented. Bead tagging iguanas facilitates this effort. Table. 2, shows all documented deaths for July – November 2015. Many iguanas become trapped in harmonica wire fencing used by many islanders, a problem that could be easily fixed by using cheaper goat wire fencing (Debrot & Boman 2014). In May 2015, two iguanas were rescued from fencing, and one iguana from a cistern. Although no deaths attributed to cats or dogs were documented, a mauled female with fresh bite marks on her back was caught. During fieldwork at NuStar's complex, we were informed that two iguanas were run over by employees. Two iguanas were assumed to have had natural deaths, these were found in the bush and a garden and their bodies looked intact (i.e. no puncture/bite wounds) (Figure. 46). Death through anthropogenic cause (Figure. 46) and dogs are the main source of mortality (Debrot

& Boman 2013). This severely limits the recovery and stability of such a small population (Debrot & Boman. (2014). Two beaded adults were found dead in May 2015, with bead codes: WB and BB. In June a marked juvenile (N), was also found dead.

Table. 2: Causes of Iguana delicatissima death on St. Eustatius documented for the period of 21st July to 23rd November, 2015.

CAUSE OF DEATH	MORTALITY
CISTERN	0
CATS/DOGS	0
FENCING	2
HUNTING	0
NATURAL DEATH	2
TRAFFIC	3
TOTAL	**7**

Figure. 46: (left image) Non-beaded adult Iguana found dead in a garden by the Island Estates (14-09-2015). St. Eustatius. (right image) Non-beaded sub adult male found by Hannah Madden, killed by traffic (18-11-2015). St. Eustatius.

4. Discussion

Iguana delicatissima profile on St. Eustatius

Considerable variation in maximum size exists across The Lesser Antillean Iguanas geographic range (Pasachnik *et al*. 2006). Breuil (2002) found the maximum size for males ranging from 111.5cm on Îlet Chancel (Martinique) to 141.5cm on Basse-Terre, and for females ranging from 108cm on Îlet Chancel to 130cm on Basse-Terre. The maximum known SVL for males is 43.4cm, and for females 40.1cm (Breuil 2002). On St. Eustatius we found the largest male SVL to be 42cm, and for females 38cm. Weight also varies greatly per island, with the heaviest male weighing in at 3.54kg (Breuil 2002). On St. Eustatius the heaviest male that we caught weighed 2.87kg. Breuil (2002) recorded the heaviest female at 3.05kg on St.-Barthélemy (female was pregnant), and 2.7kg on Basse-Terre (non-pregnant) (Breuil 2002). We found the heaviest non-pregnant female on St. Eustatius to weigh in at 2.5kg. This female, however, is fed a variety of food regularly by staff at the Kings Well Resort.

Distribution on St. Eustatius of I. delicatissima

We uncovered a highly scattered and fragmented population of iguanas across St. Eustatius (see Distribution). This could have serious consequences for an effective recovery, gene flow and a stable population. The total population has been fluctuating according to estimates between approximately 300 (Reichling 2000) and 425 (650 least conservative estimate) individuals in the last two decades (Fogarty *et al*. 2004 and references therein). Furthermore it is believed that densities

within the national parks are extremely low, and that no more iguanas remain in certain areas (Figures. 27 & 38). Interestingly Fogarty *et al*. (2004) estimated there to be between 174 and 404 iguanas in the northern hills. Reichling (2000) also reports Boven as having the highest density of iguanas. The low end of this estimate is now probably not even met. We found that at least 324 iguanas remain at the time of writing on St. Eustatius. More iguanas are to be found, however, conservative numbers should be expected. Debrot & Boman (2013) found that densities on St. Eustatius were comparable to 0.5-1% of densities documented on other islands. The low ratio between males and females on St. Eustatius compared to other islands is possibly attributed to this low density of iguanas.

Nesting

When exactly does nesting occur on St. Eustatius, and what is the incubation time of hatchlings? Currently these questions cannot be answered for wild populations on St. Eustatius. In captivity incubation took 93-96 days (Lemm *et al*. 2010). Presumably mating occurs in April-May, with nesting in June and July (Powell *et al*. 2015), therefore before this research project commenced. Clutch sizes are known to vary on different islands (Breuil 2002; Knapp et al. 2014), with estimates ranging from 13-30 (Knapp *et al*. 2014), up to 27 (Lemm *et al*. 2010) and 20-30 (Powell *et al*. 2015) depending on the island. It is unknown how large average clutch sizes are on St. Eustatius. Clutch sizes are also found to strongly correlate with the size of females (Breuil 2002). By three nests, desiccated eggs were found on the surface. This is possibly due to rats digging up eggs to eat (Powell *et al*. 2015) or egg-laying females uncovering old eggs in the process of digging a new nest (Hayes 1999). Females most likely have to use the same nesting location each year due to a lack of suitable nesting locations (Debrot & Boman 2013; Debrot *et al*. 2013).

According to Alberts (1999) and Breuil (2002), on Dominica females are known to migrate up to 900m to lay eggs. Females have been documented migrating to the coast and nesting on beaches (Breuil 2002). Breuil (2002) suggests that females might even return to the location where they were born to nest. Whether they do this on St. Eustatius is currently unknown and needs to be confirmed by a study focusing on nesting behaviour.

Juveniles

How far juveniles disperse after hatching is not known. However, juveniles and sub adults were regularly observed in close proximity of fully grown adult iguanas. This possibly indicates that there is no direct need for juveniles to disperse as long as food and shelter are plentiful. Males reaching sexual maturity, however, will directly compete with established males, as males are highly territorial (Durrell Wildlife 2001). These territorial disputes will force the lesser of two males to relocate.

It is unclear whether hatchlings make their own small burrows or opportunistically use burrows made by land crabs (*Gecarcinus ruricola*) or red faced ground lizards (*Ameiva erythrocephala*). It has also not been documented whether they also use hides during the warmest time of day, or just remain hidden under vegetation. One hatchling that we managed to capture tried to escape by hiding in a small hole in the ground, and thus uses the same escape measure as adults. If we managed to capture a hatchling we could not accurately record its weight as the weight scale was not sensitive enough. The weight of *I. delicatissima* hatchlings can, however, be considered equivalent to that of *I. iguana* (breuil 2002).

Hybridization

Hybridization is a major concern for St. Eustatius and throughout the range of The Lesser Antillean Iguana, as it is one of the main factors leading to the disappearance of the species (Knapp *et al*.

2010). Male *I. iguana* are able to outcompete male *I. delicatissima* in the same location and displace them (Knapp *et al*. 2010; Vuillaume *et al*. 2015). *Iguana iguana* males have a competitive advantage, being larger and stronger than *I. delicatissima* males, they are therefore able to mate with *I. delicatissima* females (Vuillaume *et al*. 2015). Vuillaume *et al*. (2015) found that the resulting hybrids can mate with and between parental species. They will produce viable offspring, leading to introgression (Vuillaume *et al*. 2015), and thus the loss of genetically pure populations. Hybrids of *I. delictissima* and *I. iguana*, can vary greatly in phenotype. These phenotypes can range from nearly *I. delicatissima* to nearly *I. iguana* (Vuillaume *et al*. 2015). Figures. 47 & 48 (Curtesy of Hannah Madden), illustrate different phenotypes of hybrids found on St.-Barthélemy. Vuillaume *et al*. (2015) recommends using morphological criteria defined by Breuil (2013) and genetic criteria in order to determine whether an iguana is a hybrid or not. Although I observed no Green Iguanas during this research on St. Eustatius, recognising a hybrid can be difficult as I personally experienced on Anguilla, where a presumed hybrid had *I. delicatissima* features, apart from the tail which had light barring. The identity of this iguana is under investigation by the Anguilla National Trust (Figure. 49). It is critical the population is constantly monitored on St. Eustatius, and that any Green Iguanas are immediately reported to STENAPA. Most untrained people, however, are not able to distinguish between the two species, therefore any legitimate warning might already be too late.

Figure. 47: Iguana iguana x Iguana delicatissima found on St.-Barthélemy.

Figure. 48: *Iguana iguana x Iguana delicatissima found on St.-Barthélemy. Note the clear barring on the tail.*

Figure. 49: Potential hybrid with faint bars on the tail. A DNA sample has been taken which will confirm whether it is a hybrid or not (F. Mukhida pers. comm.). Anguilla National Trust, Anguilla, 2015.

Mortality

All seven documented iguana mortalities were based on (sub) adults. Dead juveniles were not observed, possibly as these can be much harder to localize due to their size. Natural predation of juveniles by Red-bellied Racers (*Alsophis rufiventris*) has been documented by Debrot *et al*. (2013). Native predators such as Red tailed Hawks (*Buteo jamaicensis*) and American Kestrels (*Falco sparverius*) are also likely to contribute to iguana mortality (Debrot *et al*. 2013). Debrot & Boman (2014) documented 17 cases of *I. delicatissima* mortality on St. Eustatius for the period of April – December, 2012, for which most were ultimately accountable to man. Whereas we found five out of seven deaths due to man. Dogs were a major contributor to *I. delicatissima* mortality (Debrot & Boman 2014), and possibly feral cats are preventing recruitment of juveniles (Hayes 1999). Preferably dead animals should be collected to determine the reason of death if unknown; to investigate stomach contents and take opportunistic DNA samples.

Beading & Relocating Iguanas

Although the majority of the island citizens are accepting the bead tagging method for monitoring iguanas and conservation purposes, six to eight iguanas could not be beaded as property owners did not want to alter the natural look of iguanas on their land, or they were afraid that iguanas would never come back after being handled. Other residents wanted iguanas removed from their gardens. These were then released close to the Quill. A large male released in this area was, however, observed fighting with an established male. It seems that suitable habitat is saturated and cannot sustain more iguanas in this area. A better alternative would be to release iguanas in the Venus Bay area (Figure. 50), where there is suitable patch forest in the valley, and currently holds no or very low densities of iguanas. This area has the added advantage of being far from traffic or other anthropogenic dangers. It should be noted though, that iguanas, males in particular, cannot be consistently released in exactly the same area due to potential territorial disputes. Therefore all suitable habitat in the entire area should be used, and regularly monitored. Further suitable release sites should be considered such as in the area near the north of the proposed protected area (Figure. 51).

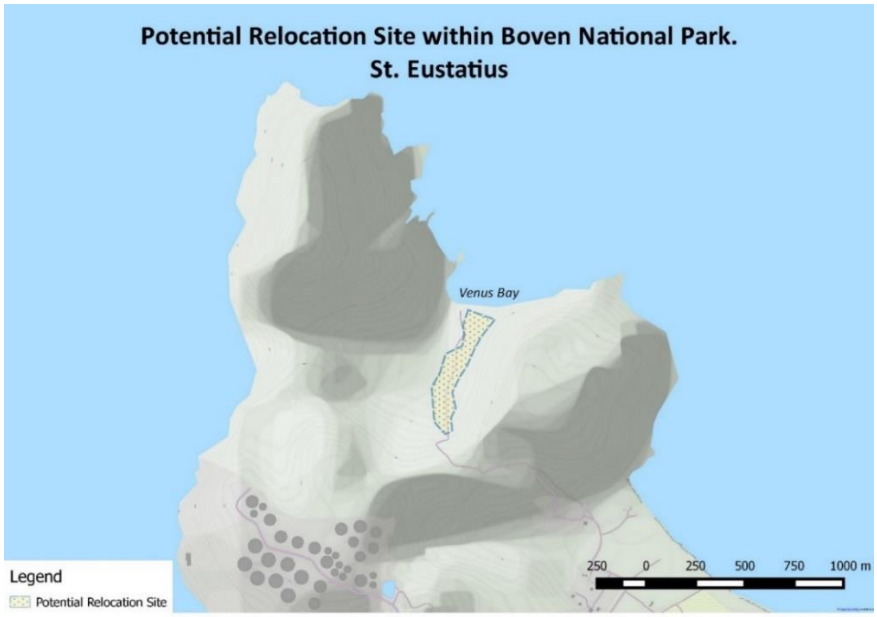

Figure. 50: Potential relocation site for iguanas by Venus Bay, Boven National Park, St. Eustatius.

Observations and indicators of I. delicatissima.

It is interesting to note that most iguanas live by roads, forest edges and clearings. Very few animals were found in areas with dense cover. It could be argued that iguanas are more difficult to find in forests than clearings. However, everyone involved in the search for iguanas had a trained eye and it is unlikely they missed any. Furthermore in areas known to have iguanas, faeces and in some cases shed skin could be found, meaning iguanas are close by. Burrows were another indicator, however it was important to check whether these were actively being used.

5. Conclusion and recommendations

Due to the rarity of the Lesser Antillean Iguana on St. Eustatius, (most likely total population probably in line with the estimate (425 individuals) by Fogarty *et al*. (2004)) and its limited distribution on the island, establishing new suitable protected areas should seriously be considered. The area between Signal Hill and Boven National Park would be a suitable area since it contains prime habitat, is still undisturbed with a confirmed nesting area, and holds a relatively large population of iguanas (Figures 26 & 51). It may also function as a release site. A lack of suitable nesting sites persists, and is a major hurdle that should be overcome to regain a healthy iguana population (Debrot & Boman 2013). Debrot & Boman (2013) found six nesting sites, whereas during this research only four confirmed nesting sites were found, three of which had eggs lying on the surface. This illustrates the scarcity of nesting sites and the need for additional new nesting areas. Strategically placing suitably constructed artificial nests could help boost the iguana population. Nests could be placed next to established nesting sites to broaden availability in an area used for nesting. This will also minimize the chances of previously laid nests being dug up. Other artificial nests can be placed in areas that otherwise have little nesting sites to offer, such as in the Quill area (Debrot & Boman 2013). Artificial nests could be large flat piles of sand and gravel placed on the spot as suggested by Debrot & Boman (2013), or by placing nest boxes. Due to the required size of nest boxes, however, this may not always be feasible *in situ*. According to Lemm *et al*. (2010), the Durrell Wildlife Conservation Trust installed nest boxes at least one meter deep. Durrell Wildlife (2001) recorded nest burrows approximately one meter long, with an egg laying chamber at the end. Nest boxes would therefore have to be large and placed in certain locations across the island, which could prove difficult. All artificial nests should be placed in a sunny spot, with little to no vegetation cover.

It is crucial that nesting behaviour is well documented. Gravid females should be consistently monitored (e.g. with GPS tags) until they lay eggs. This could uncover whether the same nesting sites are used each year, and whether multiple females use the same site. Nesting locations should be documented and monitored until hatchlings emerge. Ideally, hatchlings should be tracked to study their dispersal and fate. This could give insight into the recruitment success of *I. delicatissima* on St. Eustatius, and provide critical information on population dynamics, of which little is known at present. This may however, prove difficult due to the size and camouflage of hatchlings. Therefore it is suggested that hatchlings should be brought up in a *in situ* head starting programme, also advised by Debrot & Boman (2013) and Debrot *et al*. (2013). An *In situ* head starting and husbandry program is the most direct way of increasing population size, while also gaining scientific knowledge on specific aspects of the species, and an excellent educational tool for STENAPA (Debrot & Boman 2013).

Furthermore a management plan towards the eradication of feral goats and chickens needs to be implemented. Feral goats and chickens are a potential threat to the existence of iguanas and biodiversity on the island in general (Debrot *et al*. 2015). Goats can easily trample nesting sites (Debrot & Boman 2013), and are drastically changing the landscape of St. Eustatius. Goats cause severe erosion, and are responsible for a lack of undergrowth in forests due to overgrazing (Debrot *et al*. 2015) (T. van Wagensveld pers. obs.). Eradicating feral goats is of the highest priority, particularly in the Quill and the Northern Hills (Debrot *et al*. 2015). Allowing vegetation to grow back to its natural state, where it is not continuously being grazed upon, could have positive effects on the iguana population. It will open up habitat, previously unsuitable.

Although much of the island was investigated, many areas remain that still require an extensive (follow up) search. The following areas may hold more pockets of iguanas: the area between Kay Bay and the beginning of Rosemary lane, where there are particularly large *E. lactea* that grow as large trees along the main road (Figures. 34 & 35); The NuStar Terminal, particularly in areas by the coastal cliffs, although these are hard to reach; the slopes of the Quill; the proposed protected area and the cliffs along the beach between the Kings Well Resort and STENAPA's Visitors Centre.

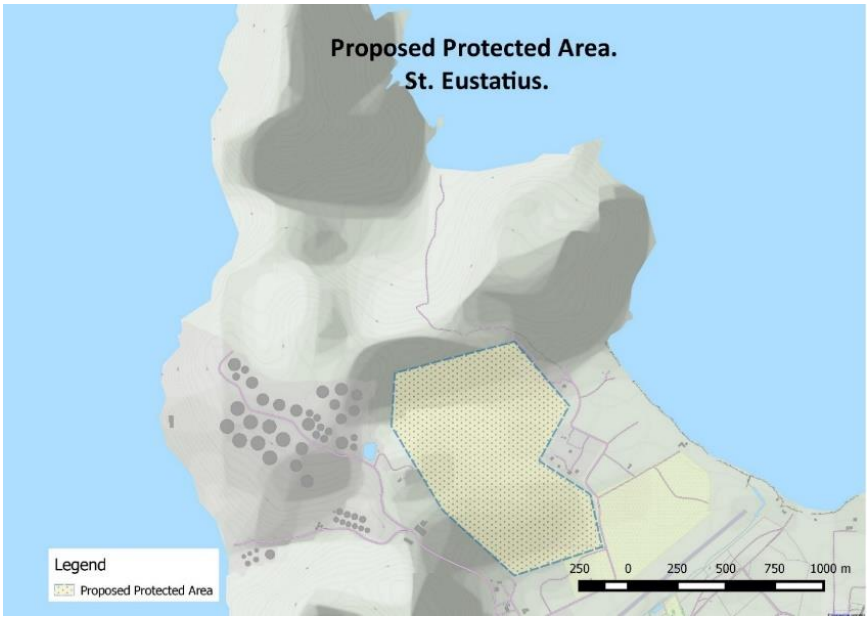

Figure. 51: Proposed protected area bordering the south of Boven National Park, which encompasses a broad array of untouched habitat, St. Eustatius.

6. Acknowledgements

I would like to give special thanks to: Hannah Madden, Ambrosius van Zanten, Thijs van den Burg and Fedor den Elzen for assisting me in the field with tracking, beading and observing iguanas. Without their help a lot of work would not have been possible. To Bart Kluskens of RAVON for this project and his help. STENAPA, for providing me with the means to conduct my research. Also to Farah Mukhida for showing me the current situation of *I.delicatissima* on Anguilla, and providing me with more sleeves to continue beading on St. Eustatius.

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Appendix A

Table of free and used bead codes.

Bead Code Available

XXX Bead Code Not Available

R	W	Y	G	B	P	O

	R	W	Y	G	B	P	O
R	RR	RW	RY	RG	RB	RP	RO

	R	W	Y	G	B	P	O
W	WR	WW	WY	WG		WP	WO

	R	W	Y	G	B	P	O
Y	YR	YW	YY	YG	YB	YP	YO

	R	W	Y	G	B	P	O
G	GR	GW	GY	GG	GB	GP	GO

	R	W	Y	G	B	P	O
B	BR	BW	BY	BG		BP	BO

	R	W	Y	G	B	P	O
P	PR	PW	PY	PG	PB	PP	PO

	R	W	Y	G	B	P	O
O	OR	OW	OY	OG	OB	OP	OO

	R	W	Y	G	B	P	O
WW	WWR	WWW	WWY	WWG	WWB	WWP	WWO
WY	WYR	WYW	WYY	WYG	WYB	WYP	WYO
WP	WPR	WPW	WPY	WPG	WPB	WPP	WPO
WR	WRR	WRW	WRY	WRG	WRB	WRP	WRO
WO	WOR	WOW	WOY	WOG	WOB	WOP	WOO
WG	WGR	WGW	WGY	WGG	WGB	WGP	WGO
WB	WBR	WBW	WBY	WBG	WBB	WBP	WBO

	R	W	Y	G	B	P	O
RW			RWY	RWG	RWB	RWP	RWO
RY							
RP							
RR	RRR	RRW	RRY	RRG	RRB	RRP	RRO
RO							
RG							
RB							

	R	W	Y	G	B	P	O
PW						PWP	
PY							
PP	PPR	PPW	PPY	PPG	PPB	PPP	PPO
PR							
PO						POP	
PG						PGP	
PB							

	R	W	Y	G	B	P	O
YW							
YY	YYR	YYW	YYY	YYG	YYB	YYP	YYO
YP						YPP	
YR	YRR		YRY	YRG	YRB	YRP	YRO
YO		YOW	YOY	YOG	YOB	YOP	YOO
YG	YGR	YGW	YGY	YGG	YGB	YGP	
YB							

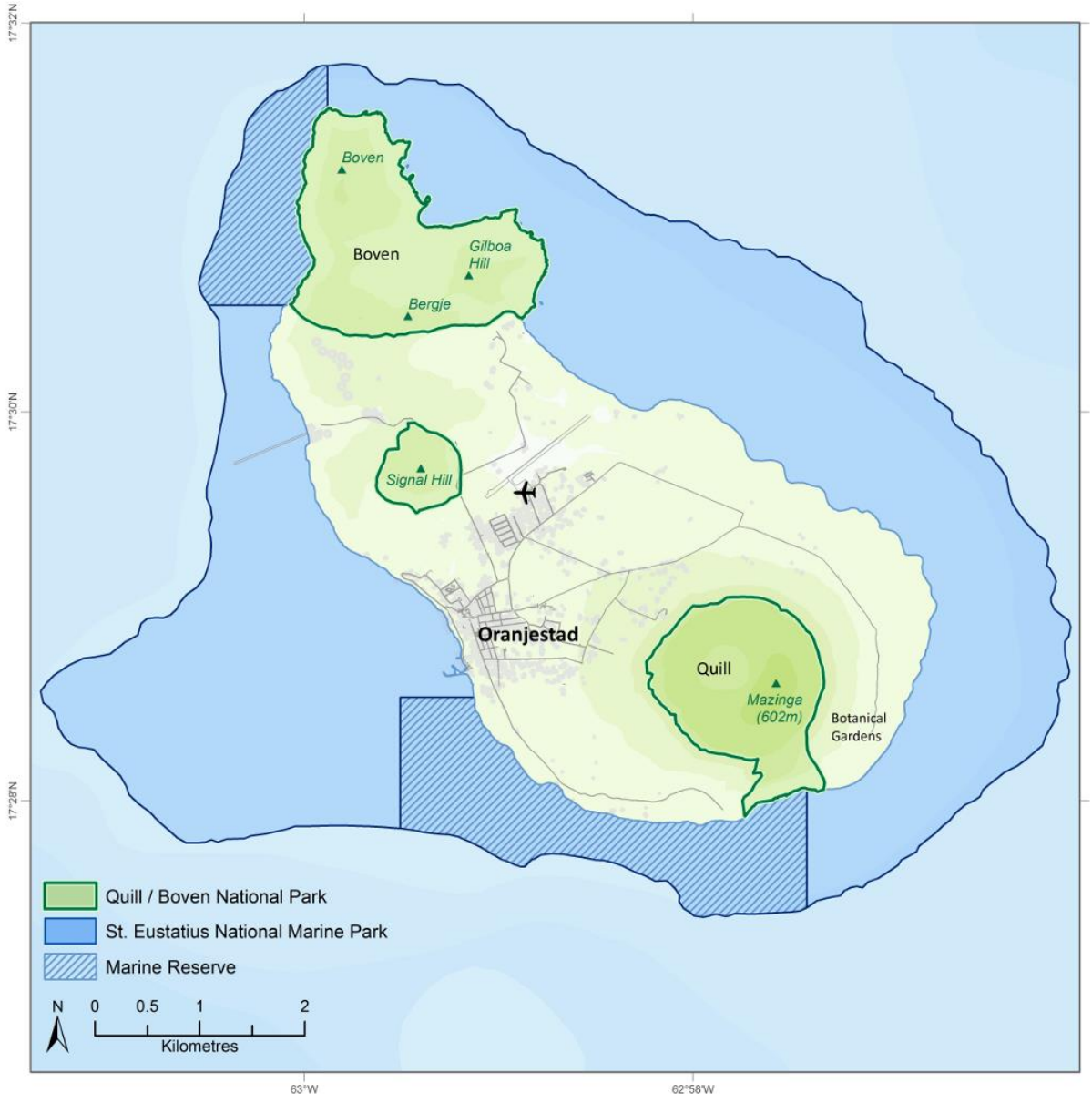
	R	W	Y	G	B	P	O
OW	OWR	OWW	OWY		OWB	OWP	OWO
OY							
OP	OPR	OPW	OPY	OPG	OPB	OPP	
OR							
OO	OOR	OOW		OOG	OOB	OOP	OOO
OG							
OB	OBR	OBW	OBY	OBG	OBB	OBP	

	R	W	Y	G	B	P	O
BW							
BY	BYR	BYW	BYY	BYG	BYB	BYP	BYO
BP							
BR	BRR	BRW	BRY	BRG	BRB	BRP	BRO
BO							
BG							
BB		BBW		BBG		BBP	

	R	W	Y	G	B	P	O
GW							
GY							
GP							
GR							
GO							
GG							
GB							

Appendix B

Map of St. Eustatius Marine parks/reserves and National Parks. Used with permission by the Dutch Caribbean Nature Alliance (DCNA). http://www.dcnanature.org/



DCNA
DUTCH CARIBBEAN NATURE ALLIANCE

Appendix C

Vegetation that I observed being used either as a form of cover or as a source of food (Fruits/Leaves/Flowers), In July-November.

(*) = Vegetation used as shelter by Adult iguanas.

(**) = Vegetation used as shelter by Sub adult iguanas.

(***) = Vegetation used as shelter by juvenile iguanas.

Iguanas found in:	**Confirmed sighting of iguana eating**	**Fruits**	**Leaves**	**Flowers**
Annona muricata (Soursop)				
Annona squamosa (Sugar apple)(**)/(***)	X		X	
Antigonon leptopus (On trees) (Corallita)				
Azadirachta indica (Neem tree)	X		X	
Bursera simaruba (Tourist tree)				
Cereus hexagonus (*)/(**)				
Coccoloba ufivera (Sea grape) (*)	X	X		
Crescentia cujete (Calabash tree) (*)				
Delonix regia (Flamboyant)				
Eugenia ligustrina	X	X		
Euphorbia lactea (*)/(**)/(***)				
Guilandina bonduc (Gray Nicker)				
Hibiscus spp.	X			X
Hippomane mancinella (Manchineel tree)	X	X		
Leucaena leucocephala (Tan tan)	X		X	
Malpighia emarginata (Acerola)	X	X		
Mangifera indica (Mango)				
Melicoccus bijugatus (Genip)				
Pandanus spp. (Razor plant) (*)/(**)				
Pilosocereus royenii (Royen's tree cactus)				
Tamarindus indica (Tamarind)	X		X	
Vachellia farnesiana (Acacia) (***)	X		X	X
Veitchia merrillii (Manilla palm)(**)	X	X		