The Isle of Misfit Species

Ecology of the invasive *Boa* on St. Croix, U.S. Virgin Islands

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APPROVAL SHEET

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The final copy of this thesis has been examined by the signatories, and we find that both the content and the form meet acceptable presentation standards of scholarly work in the above mentioned discipline.

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ABSTRACT

Non-native species pose a threat to biodiversity across the globe. The majority of modern extinctions occur on islands, and competition and predation by invasive species is believed to be a leading cause. Non-native breeding populations of *Boa* spp. are present on the Caribbean Islands of Aruba, Cozumel, Puerto Rico, and St. Croix. While the extent of the ecological harm *Boa* cause in the Caribbean is largely unknown, there is a real fear that *Boa* may place stress on native, endemic species only found on these islands.

The goal of this study is to detail a more comprehensive ecological profile of the invasive *Boa* population on the island of St. Croix in the US Virgin Islands. The primary objective is to compare DNA analysis on fecal samples and stomach contents from captured snakes supplemented by reported prey data from a social media page dedicated to the St. Croix *Boa*. This will lead to a more comprehensive prey list. A second objective is to use yearly capture and location data to map *Boa* expanse on the island and identify patterns of habitat use. Both a prey list and estimated range map will provide additional ecological data on the St. Croix *Boa* population that may be used to guide future management and removal efforts.

Boa captures were collected from the Facebook group "St Croix Snakes" between December 2018 and June 2022. All *Boa* capture data that mentioned an observed prey interaction or prey recovered during dissection were catalogued. Additionally, we combined thirty-nine snakes we captured and received from St. Croix frozen for diet analysis in 2021. Once thawed, samples were collected from the fore, mid, and hind gut and preserved in ethanol. DNA was extracted using a modified phenol-chloroform ethanol extraction and replicated using a 12S RNA primer. The resulting sequences were matched to prey using BLAST. Of the 39 samples collected, only 19 were successfully amplified using PCR. Of the 19 successful amplifications, only 7 were

matched to non-*Boa* species. The prey comprised 14.29% birds, 28.57% mammals, and 57.14% reptiles. These proportions were compared to the prey data proportions from Aruba during the early invasion, peak encounters, and decline in captures phases. Chi-square analysis suggest that the prey consumption between *Boa* on St. Croix and Aruba was not significantly different at all stages of the Aruba invasion. Correspondence Analysis suggests that the St. Croix *Boa* population, at the time of this study, is most similar to the 2013-2015 decline in capture phase on Aruba, due to the similar proportions of reptile prey consumed. In addition, "St Croix Snakes" provided prey records not present in the DNA analysis, including two native bird species, Zenaida Dove (*Zenaida aurita*) and the Lesser Antillean Bullfinch (*Loxigilla noctis*). The combined list of identified prey includes 11 species.

Boa capture data from Google Earth were georeferenced into ArcPro, and the minimum bounding geometries tool was used to create seven estimated range maps from 2012 to 2022. Kernel densities were created at 50% and 10% confidence intervals and laid over a vegetation layer to estimate habitat preferences over time. For each of the seven years, the most prominent habitat cover is deciduous, followed by disturbed habitats across a range of 50% and 10% confidence intervals. Chi-square analysis suggests that each consecutive year is statistically different from the year prior at both confidence intervals. The results produce an average yearly range expansion of 17.76 km^2/year. However, it is important to note that the range expansion that occurred during 2016 increased the *Boa* range by a magnitude of 10, from 8.49 km^2 in 2015 to 80.52 km^2.

Overall, this study established a preliminary prey base for *Boa* on St. Croix and documented their spread from 5.5 km^2 to 147.59 km^2 over 2012, 2013, 2014, 2015, 2016, 2017, 2018, 2019, 2020, 2021, and 2022. This study furthers the current understanding of *Boa* on St.

Croix, but there remains much to learn before the impacts of the population are fully understood or any meaningful elimination effort can be implemented. Further research should utilize other prey identification methods, such as the visual identification. Ground truthing and active field surveys should be conducted to enrich our current model for *Boa* range and habitat preference. More concerted efforts should be used to inform the public of findings as they become available, and a standardized way of reporting captures and sightings should also be implemented. The results of this study do not indicate the ecological disassembly that we see in other cases of invasions, but more groundwork must be conducted to measure the full scope of the effect of the invasive *Boa* on the island of St. Croix.

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CHAPTER 1:

AN INTRODUCTION TO GENUS *BOA* ON THE CARIBBEAN ISLAND OF ST. CROIX, U.S. VIRGIN ISLANDS

Islands only make up 5.3% of the Earth's landmass, yet over 61% of modern extinctions and 37% of critically endangered species are found on islands (Tershy et al., 2015). Isolation allows for novel characteristics to develop, often in a vacuum of ecological pressures such as competition and predation, which are strong drivers of evolution. This process leads to the development of unique species that are either easy prey or easily outcompeted by invasive species at the community level. The introduction of non-native species is believed to be the driving force behind biodiversity loss on islands throughout the world (Spatz et al., 2017).

Non-native species are those that exist outside of the established ranges in which they naturally occur (Executive Order No. 13112, 1999). While humans are closely linked and highly dependent upon hundreds of non-native species, some non-native species may become invasive. An invasive species is any nuisance non-native organism capable of reproducing independently of human facilitation (Executive Order No. 13112, 1999). "Nuisance" is typically defined as causing economic or environmental harm. The U.S Congress, Office of Technology Assessment (1993) has identified two primary pathways of invasion. In the first pathway, non-native species are imported to a new location by humans, where they either establish a reproductive population or are cultivated with human assistance and then escape or are released. In the second pathway, a native or non-native population already present expands to a previously inaccessible range.

Establishing the vector of invasion can provide valuable information for management and prevention of further invasion of the same or similar species. DNA sequencing has become an

effective tool for tracing the origins of invasive species like *Boa spp.* (Reynolds et al., 2013; Bushar, et al., 2015; Angeli et al., 2019). When DNA sequencing is used to match an invasive species to its geological origin, researchers and land managers can predict potential landscape spread and ecological niche. Understanding vectors of introduction can help to enact policy and practices to prevent further invasion by similar species (Reynolds et al., 2013).

The *Boa* Complex

Taxonomy

Between 1906 and 2009, *Boa constrictor* was used to describe the only extant species in the genus *Boa* (Reynolds & Henderson, 2018). With a contiguous range from northern Argentina to Mexico, *Boa constrictor* had been split into several highly debated subspecies based on range, morphology, and genetic identifiers (Reynolds & Henderson, 2018). The St. Lucia and Dominican *Boa* populations have undergone centuries of conflicting species and subspecies statuses (Laurenti, 1768; Gunther, 1888; and Reynold & Henderson, 2018). In 2009, Henderson and Powell made the most recent case to elevate the two Lesser Antilles *Boa* populations into their own distinct species. The Dominican population has since been recognized as *Boa nebulosa* and the St. Lucia population is recognized as *Boa orophias* (Henderson & Powell, 2009). While these splits were necessary to acknowledge the geographic, morphological, and genetic differences between the mainland population from those isolated in the Caribbean, it left *Boa constrictor* as the single contiguous mainland *Boa* population from Northern Argentina to Northern Mexico.

Further mitochondrial and nuclear analysis by Card et al. (2016) suggest that three distinct mainland clades exist within the genus, each loosely corresponding to the three land

masses of the Americas. Card et al. (2016) suggest the three clades should be recognized as distinct species: *Boa sigma* corresponding to the North American clade, *Boa imperator* comprising the Central American clade, and *Boa constrictor* remaining the dominant species in South America.

Thus, the genus *Boa* currently encapsulates five non-venomous species that use a muscular frame to coil around prey, preventing circulation until death (Reed & Rodda, 2009). *Boa* spp. are highly adaptable and generalist feeders, occupying habitats ranging from savannah to tropical rainforests, and even agricultural fields and urban settings (Reed & Rodda, 2019). As opportunistic feeders, *Boa* spp. will consume a variety of prey including birds, small mammals, and other reptiles (Reed & Rodda, 2009; Reinert et al., 2021). Hatchlings and juveniles tend to be more arboreal than adults, and are more active hunters until they reach maturity. As adults, their size, mass, and cryptic camouflage are better suited to an ambush predatory style (Reed & Rodda, 2009).

When Boback (2006) compared *Boa* spp. from mainland Belize to those from Crawl Cay, Lagoon Cay, False Cay, Peter Douglas Cay, and West Snake Cay, he found a shift in morphology. While mainland *Boa* spp. tend to be terrestrial, those found in the cays adapted to an environment devoid of large prey mammals and reptiles found on the mainland. Boback (2006) found that island *Boa* were roughly half the length of mainland *Boa* and approximately 1/5 the mass. Boback (2006) also found that the sexual size dimorphism found in mainland *Boa* was absent from those of the surveyed cays. The morphological differences observed in insular *Boa* support an arboreal body plan with a diet consisting largely of passerine birds, oftentimes the only food source on these small cays. It is important to note that the changes in insular *Boa*