SPATIAL ECOLOGY AND DIET OF THE ARGENTINE BLACK AND WHITE TEGU (*SALVATOR MERIANAE*) IN CENTRAL FLORIDA

By

MARIE-THERESE OFFNER

A THESIS PRESENTED TO THE GRADUATE SCHOOL OF THE UNIVERSITY OF FLORIDA IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE

UNIVERSITY OF FLORIDA

2017

To my parents, for putting me in touch with nature

ACKNOWLEDGEMENTS

I would like to express my deepest gratitude for the people who made it possible for me to fulfil my dreams, from the beginning of my work with tegus to the culmination of my thesis submission.

My committee members each spent their time and talents shaping me to become a better biologist. Dr. Todd Campbell put me on the path. Dr. Steve Johnson accepted me under his tutelage and his continuous support ensured I was able to reach my goals. Dr. Mathieu Basille's patience and persistence in teaching me how to code in R was invaluable and Dr. Christina Romagosa always knew how to keep up spirits.

Much of my work would not have happened without my colleagues and friends past and present at Florida Fish and Wildlife Conservation Commission, Hillsborough County Conservation and Environmental Lands Management and RVR Horse Rescue (where I began removing tegus in 2012) including Sarah Funck, Jenny Eckles, Liz Barraco, Jake Edwards, Angeline Scotten, Bernie Kaiser, Ross Dickerson, and everyone else who works to defend Florida from the threat of invasives while conserving Florida's unique wildlife. Their enthusiasm, dedication and passion is contagious.

I may not have survived without my volunteers and interns Kayla Williams, Haley Hanson, Christin Meilink, Nick Espinosa, Jesse Goodyear and others who worked alongside me collecting data in the field, nor my family and friends who supported me through the years, especially my husband Gabriel Rogasner.

Thank you for believing in and supporting my research.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Abstract of Thesis Presented to the Graduate School
of the University of Florida in Partial Fulfillment of the
Requirements for the Degree of Master of Science

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Marie-Therese Offner

December 2017

Chair: Steven A. Johnson
Major: Wildlife Ecology and Conservation

Populations of a large-bodied lizard, the Argentine black and white tegu (*Salvator merianae*), have become established in two distinct regions of Florida: one in the south near Everglades National Park and one in the west-central region near Riverview, Florida. Tegus are highly adaptable opportunistic omnivores, and invasions such as this can have devastating and long-lasting impacts on native ecosystems. To date, a number of preliminary investigations have been conducted on tegus in the west central region, however only superficial data have been collected on impacts on local wildlife and spatial ecology of tegus. The goals of my research were to: 1) identify habitats selected by tegus and their frequency of use; 2) identify winter refugia; and 3) describe diet of tegus in Central Florida.

I fitted nine tegus from two study sites in Central Florida with very high frequency (VHF) radio transmitters to gather location data. I used a hierarchical approach to assess habitat selection. I evaluated landscape-level habitat use within study areas (second-order) and habitat used within home ranges (third-order). Tegus were found to select for scrub habitat at second and third order at both sites but showed no overall species or seasonal trend in habitat selection. I located four winter refugia used by

tegus for brumation, all characterized as pre-dug burrows in 100% vegetative cover. In addition I collected 105 samples of tegu diets and found tegus ate plant, invertebrate and vertebrate prey at multiple trophic levels. I also found the remains of gopher tortoise hatchlings in five tegus. My results indicate that tegus are habitat generalists that readily consume vertebrate prey along with invertebrates and fruit and should be considered a significant threat to Florida’s native wildlife.

CHAPTER 1
BACKGROUND ON *SALVATOR MERIANAE* INVASION

Ecosystems and Invasive Species

Humans have facilitated introductions of non-native species across the globe. These introductions threaten human health, agricultural yields, wildlife populations and ecosystem productivity. Along with these impacts, management of invasive species is an economic burden. It is estimated that control of invasive species, and the losses they create, costs the United States up to $120 billion dollars a year (Pimentel 2005). Newly established species may not immediately have a noticeable impact on their invaded ecosystem. In fact, impacts may not be apparent for decades or longer, giving the invaders time to establish and spread (Strayer et al. 2006, Simberloff 2013). As a population of invasive species reproduces and begins to disperse, eradication becomes increasingly unlikely. As a result, long-term management and resource protection become the only viable options, which is an economic burden (Strayer et al. 2006, Simberloff 2013). As of 2016, 180 species of herpetofauna (reptiles and amphibians) had been introduced to the state of Florida, more than any state in the US (Krysko et al. 2016). With a mild climate and diverse ecosystems, Florida often has suitable conditions for introduced species to survive. Climate matching has been shown to be a reliable predictor of species establishment success, and many introduced herpetofauna hail from regions with a similar climate as Florida (Fujasaki et al. 2010, Mahoney et al. 2015, Krysko et al. 2016).

Introduced species may out-compete native species for position within a niche or benefit from the presence of humans or other introduced species (Simberloff and Van Holle 1999, Kamath et al. 2013). Islands are particularly vulnerable to effects of nonnative species introduction (Lockwood et al. 2013, Simberloff 2013); one explanation is high endemism and low biodiversity on islands compared to mainlands (Kier et al. 2009), which gives rise to vacant niches (Lekevicius 2009) that could be filled by introduced species. Although islands are geographically isolated by water, terrestrial invaders such as cats or rats may be introduced repeatedly by human activities, putting endemic island species at risk (Courchamp et al. 2002, Hulme 2009). Along with habitat destruction, invasive species are considered to be one of the leading causes of biodiversity loss (Vitousek et al. 1997) and island endemics have accounted for the majority of extinctions in the past forty years, leading to an increased need for conservation (Whittaker and Fernández-Palacios 2007).

Florida Scrub Habitat

True islands are separated from mainlands by bodies of water, causing varying degrees of geographic isolation. Fragmentation caused by habitat loss creates "islands" of terrestrial habitats that can become similarly isolated within a landscape of human dominated areas. In Florida, dry upland xeric habitat is being rapidly lost to development and agriculture (Abrahamson et al. 1990, Scott 2004, FNAI 2010) and over 80% of Florida's original scrub habitat has been destroyed (Scott 2004). The Lake Wales Ridge runs though the interior of peninsular Florida and is the state's largest region of scrub habitat. West of the ridge, in central Florida, highly fragmented peninsular coastal scrub is found throughout Hillsborough County (Abrahamson et al. 1990). Here, wildlife persisting on these scrub "islands" are at a heightened risk of local extinction. Efforts are underway to maintain and restore remaining scrub patches through county initiatives such as the Environmental Lands Acquisition and Protection Program, or ELAPP (Hillsborough County Parks, Recreation and Conservation Program 2011).

Fragmentation of scrub lands by development leads to isolation of wildlife from other populations, putting them at greater risk of extirpation and local extinction, and over 60 percent of scrub has been lost due to anthropogenic causes (Kautz 1993, Gilbert et al. 1998, Gonzalez & Chaneton 2002, Liebold et al. 2004). Like true islands, the scrub ecosystem has a high number of endemic biota and one of the nation's highest concentrations of threatened and endangered species (Christman 1988, Scott 2004).

Natural resources, such as plants and wildlife, define the unique character of a habitat, and the goal of conservation is to maintain natural resources in perpetuity. Florida scrub and surrounding xeric habitats include a variety of unique mammals, birds, invertebrates and many terrestrial herpetofauna of particular conservation concern because they are rare, endemic to scrub habitat, or ecosystem engineers (Christman 1988, Campbell 1992, Humphery 1992, Deyrup 1994, Kinlaw and Grasmueck 2012). Due to naturally limited geographic range of scrub, continued fragmentation through habitat loss, and small percentage of remaining habitat left in the state, it is critical to quickly identify and address threats to this habitat, including management of invasive species.

Tegu Ecology and History of Invasion

In Florida there have been several introductions of predatory lizards including the Nile monitor (*Varanus niloticus*) in Cape Coral and West Palm Beach, Grey's spiny tail iguana (*Ctenosaurua similus*) in Sarasota and Fort Lauderdale and smaller species such as the northern curly-tailed lizard (*Leiocephalus carinatus*), knight anole (*Anolis equestris*) and tokay gecko (*Gekko gecko*). These species exist primarily below the frost front in southern peninsular Florida. All species are known to eat small mammals, insects and smaller lizards, with the Nile monitor and spiny tail iguana posing an additional threat to medium sized mammals, reptiles and birds (Campbell 2005, Krysko 2009).

The Argentine black and white tegu (Figure 1-1), *Salvator merianae*, hereafter referred to as ABWT, a large predatory lizard, was introduced to Florida in the early 2000s (Enge 2006), likely a consequence of demand for tegus as pets. The ABWT is native to Argentina, Uruguay, Paraguay and Brazil and can be found in a variety of habitats including savannas, forest clearings and human dominated landscapes (Presch 1973, Fitzgerald et al 1991). Two separate populations occur in the state, one in south Florida in the Miami-Dade region and another in Hillsborough County in and around scrub habitat. In their native range ABWTs are known to inhabit a wide variety of landscapes, from urban parks to grasslands to forest edges and clearings (Presch 1973, Fitzgerald 1993, Juri et al. 2015, Lopez et al. 2015). They are a large-bodied lizard, growing to 145 cm in total length and weighing up to 8 kg (Lopes and Abe 1999). True omnivores, ABWTs eat a variety of foods including insects, mollusks, arachnids and other invertebrates, small mammals, amphibians, reptiles (including adult snakes and small turtles), birds, eggs and a variety of fruits (Mercolli and Yanosky 1994, Colli et al. 1998, Silva et al. 2004, Baracco 2014). Tegus are not adept climbers and forage mainly from the ground during the day. However, they are opportunistic and enter burrows to capture prey and are occasionally able to seize unsuspecting birds from the ground. Tegus are capable of preying upon rare and endangered wildlife in xeric communities including the gopher tortoise (*Gopherus polyphemus*), indigo snake (*Drymarchon couperi*), short tailed snake (*Lampropeltis extenuate*), Florida pine snake (*Pituophis melanoleucus*), sand skink (*Neoseps reynoldsi*), gopher frog (*Rana capito*), scrub jay (*Aphelocoma coerulescens*) and the endemic Florida mouse (*Podomys floridanus*) (Campbell 1992, Humphery 1992). Additionally, tegus retreat to burrows at night and during the winter months to escape cold temperatures, brumating (a form of hibernation in herpetofauna) for four months underground (Sanders et al. 2015). Tegus put Florida's wildlife at risk through predation and exploitative competition, although their ultimate impacts are still unknown.

Tegus in South Florida are known to inhabit elevated canal embankments adjacent to wetlands and the surrounding human dominated landscape (Klug et al 2014). Although impacts are not well understood, tegus in South Florida eat a wide variety of vertebrates, invertebrates and fruits and may be a seed disperser for nonnative plants (Baracco 2014) and have been documented raiding alligator nests for eggs (Mazzotti et al. 2014). Although research has assessed habitat use and potential impacts of southern populations associated with wetland and coastal habitat in Florida (Klug et al. 2014, Mazzotti et al. 2014, Barraco 2014), few studies have been conducted to asses ABWT in the dissimilar central Florida xeric uplands (Enge 2006). Reports from invaded regions in west-central Hillsborough County suggest that ABWT persist primarily along edges of human dominated landscapes bordering public lands consisting of scrub and other upland habitat (Enge 2006, EDDMaps.org, FWC.com). Knowledge from the southern tegu population is of limited use for making management decisions in central Florida because tegus persist in novel habitats here and thus may behave or impact wildlife differently. Little formal research has been conducted on Hillsborough County tegu populations. One unpublished study in 2010 made use of wildlife cameras to document tegu presence at gopher tortoise burrows on Balm

Boyette Scrub Preserve (BBSP; Kaiser 2016). Tegus were documented visiting burrows and burrow aprons but behavior in the burrows was not well documented. It was theorized tegus were frequenting burrows as a foraging site and possibly preying on gopher tortoise burrow associates. Additional research was conducted in 2013 on private land north of BBSP to trap and remove tegus for diet analysis (Offner and Campbell 2013, unpublished). The outcome of this study was not published and neither study addressed spatial ecology, which is a vital tool for invasive species management that can identify range extent, pinpoint movement corridors and highlight habitats disproportionately occupied in the landscape.

Research Objectives

In order to appropriately plan conservation efforts and manage lands in which Argentine black and white tegus occur it is important to identify areas that this species is likely to impact. Therefore, investigating habitat selection across different habitat types will aid efforts for trapping and removal of tegus and, complimented by diet analysis, highlight species vulnerable to predation and competition from tegus. One goal of my study was to examine spatial ecology of tegus in Central Florida in order to identify habitats occupied and frequently used by tegus and to estimate home range (Chapter 2). A second goal was to describe tegu diet based on data from prior studies and additional data I collected (Chapter 3). In Chapter 4, I propose best practices for continued monitoring and removal of tegus from public lands, future research goals for tegus in Central Florida and argue for statewide restrictions of this species in the pet trade.

Figure 1-1. Argentine black and white tegu (*Salvator merianae*) wearing a telemetry harness around the pelvic girdle. Photo by Marie-Therese Offner.

CHAPTER 2
HABITAT SELECTION OF INVASIVE ARGENTINE BLACK AND WHITE TEGUS IN CENTRAL FLORIDA

Introduction

Invasive species cause negative impacts to native ecosystems, harm wild and domestic animals, threaten human health and burden the economy of countries around the world (Pimentel et al. 2004, Simberloff 2013). Invaders frequently reach new habitats with the aid of humans who facilitate introductions either intentionally or accidentally (Hulme 2009; Lockwood et al. 2013). Once established, nonnative wildlife may have deleterious effects on native species through direct or indirect competition and predation. Impacts caused by an invasive species are sometimes not apparent for many years after initial introduction (Pimentel et al. 2004, Simberloff 2013). This time-lag gives invaders time to adapt to their niche within the new environment, reproduce and disperse.

It is necessary to identify the resources and habitats that may be impacted by the presence of an introduced species. Natural resources define the unique character of a habitat, and habitats can be altered by the introduction of invasive species. The goal of conservation is to maintain natural resources in perpetuity. Direct intervention through land stewardship is routinely required to prevent degradation of natural areas by human growth and development and from the introduction of invasive species (Lockwood et al. 2013, Simberloff 2013).

Prevention, early detection and rapid response are the best solutions to limiting the establishment and spread of introduced species (Burnett and Kaiser 2010, Maxwell et al. 2007). As time passes, established invaders can become widespread and eradication and control costs increase. Understanding where to look for an inconspicuous invader can direct early detection initiatives and facilitate removal. Furthermore, this knowledge can provide insight into a species' potential for impacts during risk assessments (Mehta et al. 2006).

Salvator merianae, commonly known as the Argentine black and white tegu, is a terrestrial, omnivorous lizard native to South America (Presch 1973). Argentine black and white tegus (ABWT) can grow to be as large as 145 cm total length and weigh up to 8 kg (Lopez and Abe 1999). The species ranges widely throughout Brazil, Argentina, Paraguay and Uruguay, from the Amazon basin near the equator to east central Argentina (Presch 1973). Florida's climate is similar to climate within the native range of ABWT, with a mild cold season where temperatures rarely drop below freezing. In the winter, when temperatures are insufficient for thermoregulation, ABWTs brumate for up to four months (Milstead 1961, McEachern et al. 2014, Sanders 2015). In the spring, males emerge first, followed by females, and mating occurs (Fitzgerald 1993). Females lay a clutch of 10-45 eggs that hatch during the late summer (South America) and early fall (Florida) (Fitzgerald 1993, Pernas et al. 2012, Naretto et al. 2015). Juveniles feed primarily on arthropods, but begin adding vertebrate prey and fruits to their diet as they age (Colli et al. 1998, Mercolli and Yanosky 1994).

Tegus have been introduced to the state of Florida multiple times and two confirmed breeding populations of ABWT, established since the early 2000s, now exist in the state (EDDMapS.org, Pernas et al. 2012, Barraco 2014). The population in South Florida has received much attention in recent years (Pernas et al. 2012, Mazzotti et al. 2014, MaEachern et al. 2014, Barraco 2014, Klug et al. 2015). However, comparatively little is known about the tegu population in Central Florida (Hillsborough County).

Trapping efforts by the Florida Fish and Wildlife Conservation Commission (FWC) targeting this population from 2013-2016 indicate the population is less dense and not as widespread as in the south. Individual ABWT in South Florida are frequently found in and around wetlands and disturbed habitat (Mazzotti et al. 2014, Klug et al. 2015). In contrast tegus in Central Florida are often reported from regions in and around scrub and xeric uplands (EDDMapS.org, personal observation).

The presence of congeners and climate match between the native range and introduced range have been implicated in the likelihood of successful establishment of an invader (Ferrira et al. 2002, Bomford et al. 2009, Mahoney et al. 2014). Hillsborough County and the native South American range of ABWTs have similar proximity to the equator, with invaded regions as far north of the equator as the middle southern extent of tegu native range is south (IUCNredlist.org). Tegus are large diurnal, terrestrial, opportunistic omnivores, and no other ecologically similar species exists in the introduced range in central Florida. However another smaller insectivorous Teiid, the six lined race runner (*Aspidoscelis sexlineata*) is common to scrubby habitat in the region. Although not a congener, the presence of this Teiid could indicate ABWTs may indeed do well in scrubby upland habitats.

Scrub is a vulnerable ecosystem in decline primarily due to habitat loss from development (Scott 2004). The scrub ecosystem has numerous endemic biota and also one of the nation’s highest concentrations of threatened and endangered species (Scott 2004). Protection of scrub is a priority in Hillsborough County, Florida. Here, scrub is found sporadically throughout the county and natural corridors between patches are limited, ill-defined or interrupted by urbanization (Abrahamson 1990). This habitat fragmentation increases risk of species extirpation in local scrub communities and emphasizes the need for protection (Gilbert et al. 1998, Gonzalez & Chaneton 2002, Liebold et al. 2004).

Although ABWT are reported in and around scrub habitat, a mosaic of heterogeneous landscape exists within Hillsborough County and includes wetlands, forested uplands, urban areas, pasture and cropland. No formal studies of ABWT resource use or habitat selection have been conducted here. Resource use is the amount that a resource within a habitat is exploited by an animal within a fixed period of time. Habitat selection is the intentional, preferential use of some habitats over others by an organism. It is a hierarchical process that drives establishment of wildlife within a new environment (Johnson 1980, Mayor et. al. 2009). Habitat selection studies are interested in estimating the probability that a defined habitat is selected (or avoided) over other habitats. The theoretical framework for habitat selection is organized into four levels of increasing specificity (Johnson 1980). First order selection is the geographical range of the species, second order selection is the home range of individuals within the population, third order selection identifies habitat within the home range from which resources are obtained and fourth order selection identifies the specific location among many where the resource is acquired (Johnson 1980). Resource availability may change through time, and this may influence what habitats are used by animals. After emerging from brumation (a period of inactivity similar to hibernation), adult tegus show a seasonal burst of activity in the spring followed by declining activity in the summer and fall until tegus enter brumation to seek shelter during cold winter months (Fitzgerald et al. 1993, Lopes and Abe 1999, Juri et al. 2015, McEachern et al. 2015). During months of activity tegus may seek mates, food, and water and disperse to new habitat. Survival and reproduction depend on access to biotic and abiotic resources. Adaptations may aid (or prevent) resource acquisition within the environment.

Tegus within Hillsborough County have historically been reported from multiple habitats including disturbed and natural areas (EddMapS.org), demonstrating little evidence of a population-level consensus in habitat use. Private properties utilized by tegus are a challenge to sampling efforts for population-level habitat selection studies. For this reason radio telemetry was used to understand habitats selected by individual tegus. The location of individual tegus outfitted with transmitters can be triangulated at a distance from areas accessible by researchers and overlaid on satellite imagery to identify utilized habitat without needing to access restricted areas.

Wildlife and habitat are linked. Impacts on seed dispersers such as rodents, or ecosystem engineers such as the gopher tortoise may alter a habitat in time. Without intervention it is likely ABWTs will continue to thrive in Florida and could have long term impacts on species diversity and abundance on local wildlife in Central Florida habitat. Understanding habitat use of the Argentine black and white tegu in central Florida will aid in identifying natural resources that could be affected by their presence.

The goals of my study were to determine 1) habitat selection at landscape-level and within home ranges by ABWTs and 2) location of winter refugia, where tegus seek thermal insulation during cold months when they enter a seasonal period of inactivity known as brumation. Further, because tegu behavior changes by season, with inactivity throughout the winter followed by a burst of activity in the spring and declining activity in the summer and fall (Fitzgerald 1993, Sanders 2015), I wanted to determine if habitat selection differed among seasons. To achieve these goals, I outfitted tegus with transmitters on a harness and utilized radio telemetry to monitor the location of individual tegus throughout the study. When observed at regular intervals, patterns of habitat use will begin to emerge. If tegus in Central Florida are primarily procuring resources from dry upland habitat, scrub and other xeric habitat will make up the majority of tegu home ranges and tegus will be located in this habitat more frequently than in others. In addition, tegus will have larger home ranges in spring after emerging from brumation (and thus have a larger home range) and that no activity would occur during winter brumation.

Methods

Study Site

My study areas were portions of two preserves located in Hillsborough County (Figure 2-1). Balm Boyette Scrub Preserve (BBS) and Rhodine Scrub Preserve (RS) are located 7km east of Apollo Beach, Florida with RS located 4km north of BBS. I selected these preserves because of their rich history of tegu reports and prior agency-lead investigations. Both Hillsborough County and the FWC have conducted tegu related fieldwork on these sites. Although the first records of tegus from this population were approximately 16km to the east, most tegus are now reported from the rural and urban areas surrounding BBS and RS (EDDMapS.org). Both sites have a history of tegu presence starting in the early 2000s, and both are bound by a mosaic of public roads, houses, agriculture fields and ruderal lands.

My primary habitat of interest on BBS and RS was scrub, however both preserves contain a mixture of xeric and hydric soils and nearby habitats included pine flatwoods, xeric hammock, ephemeral ponds and wetlands adjacent to steams. The dominant vegetation in the study area on both sites was saw palmetto (*Serenoa repens*), which grew so thick as to be impenetrable on foot in some areas. In RS live oak (*Quercus virginiana*) and pine (*Pinus spp*) formed a closed canopy on portions of the property. In BBS tall pines and live oak formed an open canopy with dense stands of scrub oak (*Q. ilicifolia*) growing in some burn units. Both BBS and RS are fire managed lands. Land within the preserves is sectioned by fire lanes, which are mowed at regular intervals to maintain a 3m wide path of either bare sand or herbaceous plants.

The southern edge of BBS is bordered by a 70m wide electrical utilities right of way operated by TECO (Tampa Electric Company). The right of way was used daily during the course of the study by heavy machinery and construction crews installing updated utilities. Pallets of equipment and supplies lined the eastern southern edge of this corridor. Prior to the study, the right of way had been maintained and periodically grazed by cattle. The vegetation consisted of grasses and short herbaceous plants with clumps of palmetto along the perimeter fence.

Similarly, the private properties to the south of this right of way featured well-mowed grassy fields intermittently grazed by cattle. A clump of palmettos and live oak remained on the east end of one property. A 150ha commercial tomato farm shared a border with this private property and the utility right of way. This agricultural field was planted, harvested, cleared and planted again during the course of the study. The agricultural field featured bare sandy soils with rows of tomato crops, bordered by thick clumps of palmetto along the perimeter fence.

Data Collection

To acquire study specimens, I set box traps measuring 30”x12”x12” in locations where tegus were known to visit as demonstrated in previous investigations by

Hillsborough County and FWC, such as along fences or near gopher tortoise burrows. I placed traps in bushes in the shade or partially covered to provide shade and airflow. I baited traps with a whole, raw chicken egg and replaced it every week if the egg had not been consumed. Water was provided and traps were checked daily in accordance with my UF IACUC protocol (# 201508846). Trapping occurred in two phases, the first from Mar-Sept 2015 and the second from Mar-Sept 2016. I did not trap during months where tegus exhibit reduced activity from late October through mid-February, although radio tracking was conducted year round.

I assembled transmitter harnesses by attaching radio transmitters (Holohil PD-2 or SI-2) to stainless-steel ball chain. Transmitters emitted pulses between frequencies 164 MHz and 168 MHz. As I caught tegus they were weighed and measured, fitted with radio transmitter harnesses around the pelvic girdle and released at the site of capture. All captured tegus weighing over 1000g were outfitted with harnesses. To find tegus once released, I used triangulation methods instead of close approach so as not to disturb the tegus and influence their movement. Three times a week I triangulated tegu positions by standing at predetermined stations and taking an azimuth bearing in the direction of the strongest radio signal. I recorded GPS coordinates of stations along with the average azimuth bearing, temperature, humidity, and weather conditions. If tegus remained in the same location for more than three sessions, I found exact locations using telemetry to confirm disposition of tegus or retrieve dropped harnesses. If tegus were tracked to burrows, as in winter months, I recorded the location of the burrow and monitored it regularly until tegu emergence. Additionally, I matched burrows to likely burrow architects (gopher tortoise, armadillo, rabbit, or tegu). I caught telemetered tegus periodically to adjust harness fit, measure, and weigh. I retrieved and removed tegus at the end of the study where possible.

Data Analysis

To analyze movement patterns and habitat use of tegus I used the R software packages sigloc (Berg 2014) and adehabitat (Calenge 2006), which is subdivided into adehabitatHR for home range analysis and adehabitatHS for habitat selection analysis. Of the eleven tegus fitted for harnesses, data were insufficient for two individuals. This resulted in nine tegus (five females, four males) ultimately used for spatial ecology analysis.

I entered azimuth reading stations and bearings into the sigloc program to extract a GPS coordinate for each time a tegu's position was located in the field. I screened triangulated positions for accuracy utilizing ellipse errors generated within the program and removed locations if they were recorded at a distance further than was possible for a tegu to move within the time between the previous and next locations. I compiled triangulated positions for each tegu and combined them with known exact locations (e.g. tegus in winter burrows) to produce a list of GPS coordinates, hereafter called relocations.

I fed all relocations into a data frame and used them to calculate tegu home ranges using Minimum Convex Polygon (MCP) methods in the software package adehabitatHR (Calenge 2006). To understand habitat selection I chose the 100% MCP over kernel analysis for two reasons. First, recent research indicates MCP is a more accurate representation of herpetofauna home range, especially when smoothing values for kernel analysis cannot be reliably determined (Row and Blouin-Demers 2006, Kay et al. 2017). Second, due to the limitations of the data and the challenges this created for reliably estimating home range size, 100% MCP was more appropriate for understanding habitat selection, including regions that tegus may move through but not spend much time. Finally, the focus of my study was on habitat selection and not home range estimation methods, and using a hierarchical approach to understand resource use diminishes the importance of home range methods.

I grouped location data by tegu and by season. I defined seasons as the four sets of three month intervals that primarily coincide with the spring (Mar-May), summer (June-Aug), fall (Sep-Nov) and winter (Dec-Feb) in the northern hemisphere and which reflect patterns of seasonal tegu activity. Although fewer tegus are active in November and tegus in in my study entered brumation as early as mid-October, I chose to include November with the fall months to ensure time periods were consistent across analyses. I exported the 100% MCP for each tegu in each season as a GIS layer in UTM 17 N coordinate reference system. Using QGIS, I overlaid the home range polygon with an existing layer of statewide land use land cover compiled from 2004-2016 by regional Florida Water Management Districts. I cut a new layer the same size and shape of the 100% MCP including the associated habitat within that home range. Along with the study area, I exported these polygons to R where area was calculated for each MCP and habitat polygons therein and tegu relocations were plotted on top of the image. Using this technique I was able to count the number of relocations of a tegu in a defined habitat for third order habitat selection analysis, and to calculate the area of each habitat available to a tegu for both second and third order habitat selection analysis.

Manly’s Selection Ratios are derived from work by Johnson and compare the proportion of available habitat to the proportion used (Johnson 1980, Manly et al. 2002).

Three study designs are considered, which are hierarchical in nature. Design I studies measure use and availability at population level and individual animals are not identified, design II studies measure habitat use (as home range) of identified animals against habitat available for all animals in the population and corresponds to second order habitat selection, and design III studies measure both use and availability for individually identified animals and correlates with third order habitat selection (Johnson 1980, Manly et al. 2002). I carried out design II and design III habitat selection analysis in the software package adehabitatHS (Calenge 2006). For design II analysis, the boundaries of the study sites (either RS or BBS) defined the habitat to which every tegu within that site had access. I compared habitat within home range polygons to habitat within the study site to determine if habitat was selected in proportion to availability. For design III analysis I compared number of relocations within each habitat to habitat availability inside each tegu's seasonal home range. I preformed Chi-square analysis to determine if strong habitat selection was occurring and if habitat use was dictated by individual tegus or at the species level.

Manly Selection Ratios are drawn from a unimodal distribution and it is assumed that on average all animals within a population prefer to select the same habitat to acquire resources (Manly et al. 2002). Seasonal cycles and tegu age or sex may influence habitat selection (Fitzgerald et al. 1993, Juri et al. 2015, McEachern et al. 2015). To control for variation among age classes I used only adult tegus during the course of the study. I used eigenanalysis to visually explore sex and seasonal trends in tegu selection for (or avoidance of) habitat types. Eigenanalysis of selection ratios is an exploratory method that can expose variation in resource selection among individuals. It utilizes an additive linear partitioning of the White and Garrott statistic (White and Garrott 1990). Variation in odds ratios (OR) of selection are maximized to examine selection patterns between individuals. Greatest variation occurs along the first axis if the majority of tegus select the same type of habitat, however if multiple habitats are selected then those habitats will be distributed along multiple axes, thus exposing patterns in habitat selection, if any exist, among seasons and between sexes. I evaluated tegu habitat selection in both the design II and design III study and made conclusions based on the resulting factor loading for habitat variables along the factorial plane.

Results

Tegu Tracking

I captured nine adult tegus (five females, four males) in the BBS study area. However one female was too small (790g) so I did not fit her with a transmitter harness. As seen in Table 2-1, tegus outfitted with transmitter harnesses varied in total length (mean = 93.44cm ± 8.64, range = 81.1cm-106.36cm) and mass (mean = 1686g ± 379, range 1100g-2300g). Two tegus (one male, one female) dropped transmitters within a week of deployment with only two and one relocation point collected respectively and so were removed from the analyses. Four tegus lost their harnesses; two after deterioration of the ball-chain attachment (tegus TL3, TL5) and two after becoming entangled in vegetation (TL8, TL12). This resulted in considerable variation between the minimum number of relocations (n = 9) and maximum number of relocations (n = 100) for tegus used in my analyses.

In RS I captured one male and two female tegus, each of which I fitted with transmitter harnesses. Two of these animals (TL9, TL10) apparently wandered away from the study site after 187 days and 227 days and were not able to be relocated. Two large radio towers directly adjacent to RS caused signal interference with receivers across all frequencies (164mHz to 168mHz) and I was not able to hear pulses from transmitters (and therefore locate tegus) in the immediate direction of these towers. This created regions where I was unable to accurately determine animal locations, although tegus often moved out of these areas within 24-72 hours. This occurred at the BBS site as well, but the effects of the towers were not as extreme since the radio towers were further away. Additional sources of interference came from seasonally frequent thunderstorms in the summer and radio communication and heavy machinery from nearby construction sites.

I tracked the movements of 9 tegus in total from April 2015 through October 2016. Two tegus were followed for all four seasons during the study period, and several tegus appeared in the data set for at least two seasons (Table 2-2). Tracking revealed seasonal variation in activity level, and therefore home range size. As I predicted, tegus had heightened activity in the spring after they emerged from brumation. This was followed by declining activity through summer and fall until a period of no, or nearly no activity, as they entered brumation again for the winter. Average temperatures during the brumation period from October 2015 through February 2016 remained above freezing and were occasionally relatively warm (Table 2-3) with maximum average bi-weekly temperature climbing as high as 27°C but dropping as low as 9°C. Despite many days of warmer weather, tegus did not move away from their burrows.

Home Range

Home range size for tegus was highly variable by season (Table 2-4). As expected, tegus did not move much during the winter months when they were in burrows. Since this period of inactivity did not represent a range, *per se*, winter locations were not included in further analyses. The smallest home range was that of a female tegu in the summer (0.335 hectares) and the largest was a male in the spring (144.937 hectares). Average home range in hectares varied among seasonal averages (total: 17.736 ± 33.959, spring: 36.531 ± 54.777, summer: 13.959 ± 24.393, fall: 5.134 ± 3.206) and by sex (male: 22.343 ± 44.249, female: 12.13 ± 20.167). Uneven sampling may have contributed to some of the variation in home range sizes I observed (Table 2-4). In RS one male tegu (TL11) overlapped 100% of a female tegu's spring home range (TL10) but no other overlaps occurred at that site. In BBS three tegus showed periodic home range overlap (TL3, smaller male, TL4, larger male, TL7, female). In spring 2015 the smaller male (TL3) overlapped 17% of the larger male's home range (TL4), while the female's home range (TL7) overlapped 84% of the smaller male's (TL3) and 92% of the larger male's (TL7) home range. In fall 2015 the smaller male tegu (TL3) was no longer in the study, however the large male tegu (TL4) overlapped 45% of the female tegu's home range (TL7) and 99% again in spring 2016.

Habitat Selection

Results of Chi-square analyses for design II (second order) data show tegus in the RS and BBS groups did not use available habitat in the same proportion across the study sites (RS: $X^2 = 364567$, df = 20, $p < .001$; BBS: $X^2 = 818670$, df = 98, $p < .001$) and habitat selection within study sites was non-random (RS: $X^2 = 583630$, df = 25, $p < .001$; BBS: $X^2 = 2572618$, df = 105, $p < .001$). Average habitat selection was not in proportion to available habitat at second order and tegus showed individual variation in habitat use at both sites (RS: $X^2 = 218063$, df = 5, $p < .001$; BBS: $X^2 = 1753948$, df = 7, $p < .001$). Odds ratios (OR) for selection and Bonferroni confidence intervals varied at second order by habitat and study site (Figure 2-2, Figure 2-3). The utility right of way, which did not occur on RS, was significantly selected by tegus at BBS [Odds Ratio (OR) = 6.429, SE = 1.722] and scrub habitat was selected on both sites (RS: OR = 1.506, SE = 0.169, BBS: OR = 1.85, SE = 0.166). Tegus exhibited a slight trend in selection for urban habitat on both sites (RS: OR = 1.17, SE = 0.087; BBS: OR = 1.359, SE = 0.226). On RS, tegus showed a trend in selection for upland forest (OR = 1.23, SE = 0.269) but avoidance of this habitat on BBS was statistically significant (OR = 0.386, SE = 0.096). Other avoided habitats at second order included pasture/rangeland (RS: OR = 0.279, SE = 0.079; BBS: OR = 0.341, SE = 0.091) and wetlands, which were more strongly avoided by BBS tegus (RS: OR = .955, SE = 0.121; BBS: OR = 0.102, SE = 0.019). Rural habitat was avoided by RS tegus (OR = 0.453, SE = 0.077), whereas BBS tegus demonstrated a trend in selection for this habitat (OR = 1.132, SE = 0.2).

Factor loading of habitats in eigenanalysis for second order habitat selection at RS and BBS did not cluster according to season (Figure 2-4, Figure 2-5). In RS, individual tegus selected either for urban and scrub habitat or neither but this was likely due to geographic proximity of the two habitat types. In fall of 2015 and the following spring of 2016 one tegu strongly selected upland forest habitat within its home ranges (TL10). Another tegu selected for urban habitat in the summer of 2016 but scrub habitat in the spring of the same year (TL11). The third tegu was only analyzed for a single season but strongly selected for rural habitat (TL9, fall 2015). In BBS tegus tended to select for only scrub or utilities or both scrub and utilities. Two tegus were captured and documented only in the northern portion of scrub habitat within the study site, but the utilities corridor was at the extreme southern boundary of the scrub. Tegus in the southern region of the study site used both the utilities corridor and adjacent scrub.

Several tegus in the design III study (third order) in both RS and BBS demonstrated significant habitat selection within their seasonal home range (TL10 spring 2016: $X^2 = 6.137$, df = 2, $p < 0.047$; TL11 summer 2016: $X^2 = 22.615$, df = 1, $p < .001$; TL9 fall 2015: $X^2 = 26.321$, df = 1, $p < .001$; TL12 summer 2016: $X^2 = 14.905$, df = 0, $p < .001$; TL12 fall 2016: $X^2 = 11.311$, df = 0, $p < .001$; TL4 summer 2015: $X^2 = 32.149$, df = 4, $p < .001$; TL4 summer 2016: $X^2 = 9.372$, df = 1, $p < .003$; TL4 fall 2016; $X^2 = 17.191$, df = 1, $p < .001$; TL5 summer 2015: $X^2 = 25.256$, df = 2, $p < .001$). Odds ratio analysis at third order showed slight variations from second order, with a trend in selection for upland forest and scrub habitat at RS, although Bonferroni confidence intervals showed individual selection for scrub was highly variable (Figure 2-6; Figure 2-7; upland forest: OR = 3.129, SE = 1.429; scrub, Lower 95% CI = -0.642, Upper 95% CI = 6.9: OR = 7.885, SE = 7.186, Lower 95% CI = -11.072, Upper 95% CI = 26.842). Rural habitat was avoided in RS (OR = 0.147, SE = 0.098) but was strongly selected by some animals in BBS (OR = 26.148, SE = 9.226). Utilities were also strongly selected in BBS (OR = 46.303, SE = 22.444) and scrub habitat showed a trend in selection among individuals (OR = 3.258, SE = 1.171). In BBS wetlands and pasture/rangeland were avoided (wetlands: OR = 0.294, SE = 0.154; pasture/rangeland: OR = 0.016, SE = 0.012). Eigenanalysis demonstrated individuals did not cluster according to habitat, season or sex at third order and confirmed the selection ratio analysis.

Winter Refugia

In 2015 I tracked four tegus to winter refugia (burrows), two from the RS group (TL9, TL10) and two from the BBS group (TL4 and TL7). I observed tegus entering brumation in late October or early November. Burrow shape and size indicated initial burrows were constructed by armadillos but did not show signs of recent activity. The female tegus (TL7, TL9, TL10) were not detected outside their burrows nor did they move to different burrows after they entered brumation until emergence in mid-March. The battery of the transmitter of TL9 failed during brumation, but due to her location on private property under a tree in extremely dense foliage it was not possible to excavate the burrow to retrieve the tegu and she was not subsequently caught the following spring. All four tegus chose burrows that were completely covered by brush, with two burrows (TL7, TL10) located in dense vegetation on habitat edges between natural areas and private property. Two tegus (TL4, TL9) chose burrows located in scrub situated under palmetto roots. Twice, TL4 chose hibernacula under palates of equipment used by contractors working on the utilities easement and had to relocate to a new refugia.

Discussion

My analysis revealed that individual selection is what drives variation in habitat use of invasive tegu lizards at my study sites. Tests for second order habitat selection showed significant differences in habitat selection among individuals. Additionally, third order statistics indicated that tegus selected specific habitats within their seasonal home ranges, and this varied considerably among individuals. As a result, at the species level tegus tend to be habitat generalists, both when selecting home range (second order) and when selecting habitat within the home range (third order).

Odds ratios and lower confidence intervals for scrub habitat at second order were greater than one, indicating significant selection for scrub when available in a tegu's home range, which aligned with my original prediction. However tegu association with scrub was not as strong at third order. Here, as in second order selection, odds ratios were greater than one and upper confidence intervals were significantly above one. However, lower limits of the confidence intervals were below one, indicating a weaker trend in selection. In contrast, second and third order odds ratios and upper and lower confidence intervals were below one for wetland habitat, showing that tegus at my sites avoided wetlands. One exception to this was shown by tegu TL10 in the spring. This lizard used wetland habitat in RS during spring, but at no other time; possibly during a dispersal event after brumation. This finding coincides with results of tegu land use in South Florida (Klug et al. 2015) in which natural wetlands were used proportionately less than disturbed upland as a movement corridor.

Tegus in my study used disturbed, human-altered landscapes disproportionately and dissimilarly between sites. My prediction that tegus heavily use disturbed landscapes was not entirely accurate. Landscapes dominated by shrubs and grasses (e.g. pasture/rangeland and rural), similar to native habitat of tegus and those described by Klug et al. (2015), were either used in proportion to availability or avoided by tegus in central Florida except in one instance. Heavy selection for rural habitat at third order at BBS could have been facilitated by its adjacency to scrub, utilities and urban habitats, whereas in RS this habitat type was positioned opposite these habitats and avoided. The most heavily selected habitat in BBS at both second and third order was the utilities right-of-way, a disturbed habitat which did not exist at RS. The utilities right-of-way featured well-mowed grass with artificial cover in the form of large wooden pallets and metal utilities poles that resembled large fallen tree trunks in size and positioning. In addition, the right-of-way was bordered by barbwire fence along which grew clusters of palmettos. I often located tegus along this edge and they appeared to be using the palmetto roots and leaf litter as nighttime refugia. With odds ratios greater to or very close to one at both sites, tegus did not avoid urban habitat overall. In RS urban areas were largely residential neighborhoods with manicured lawns, however in BBS the urban region consisted of 10 acre plots of land with homes, barns, grassy, well-mowed lawns and small patches of palmettos and vines. Urban areas offer potential food resources (rodents, cockroaches, cultivated fruits) and tegus may be choosing to associate with this habitat in order to access those resources despite the lack of vegetative cover and associated risks (such as dogs and lawnmowers). Upland forest habitat in BBS was avoided, despite being the largest available habitat type at that site. Across both sites, locations of tegus within the landscape tended to strongly coincide with habitat that was selected at the landscape level and locations did not tend to occur in habitats that were avoided. This indicates that tegus demonstrate a hierarchy where use of habitat at third order can be predicted by habitat selected in home ranges at second order. There were two exceptions in BBS where both wetlands and upland forest were slightly more selected at third order than at second order, but still avoided overall. Conversely, there was a dramatic increase in selection for utilities and rural habitat for tegus in BBS at third order compared to second order, but this was likely driven by two individuals and not indicative of the average tegu within the population.

When selecting winter refugia, two tegus selected burrows on the edge of urban areas (TL9, TL7), one tegu selected a burrow in scrub (TL10) and one (TL4) selected a burrow in the utilities right-of-way. This tegu originally selected refugia three times along the utilities corridor but was disrupted twice by construction and forced to relocate. As documented in previous studies, tegus used preexisting burrows for brumation (Fitzgerald et al. 1991, McEachern et al. 2015). It is unknown weather tegus left burrows to bask during the winter months; however observations during telemetry sessions made at burrows indicated there was no disturbance at the burrow entrances which were partially or entirely obstructed by leaf litter.

Although tegus avoided some habitats, no habitat appeared to be a significant barrier to tegu movement in my study. Individual-level selection, rather than a general species trend, explained variation in selected habitat. This highlights the adaptability of ABWTs and indicates their ability to successfully establish in other regions should they be introduced to another hospitable climate in sufficient numbers. This adaptability is likely correlated with the wide range in which Argentine black and white tegus occur in their native habitat; from tropical eastern Brazil to subtropical central Argentina.

Sample size was limited (n = 9) in my study and additional animals may have revealed stronger trends. However, the broad individual variation in habitat selection observed here sets a precedent for management strategies to include multiple habitats in trapping and survey efforts and underscores the emphasis on trapping in multiple habitat types. The fact that tegus chose scrub at my sites is especially alarming. Given time and continued propagule pressure, tegus are certainly capable of colonizing other natural areas in central Florida, such as the Ocala National Forest (ONF). There are several isolated tegu records from this region and adjacent areas to the south (see tegus point map at EDDMapS.org). The ONF is the “World’s largest contiguous sand pine scrub forest” (https://www.fs.usda.gov/ocala), and should tegus eventually become established here land managers may be faced with a scenario similar to the invasion of the Everglades by Burmese pythons.

My study also creates a foundation for future research to understand tegu spatial ecology in an urbanized introduced range. Argentine black and white tegus are omnivores and known dietary generalists capable of eating species protected by state law, such as alligator eggs (Mazzotti et al. 2014) and hatchling gopher tortoises (see Chapter 3). Paired with their ability to subsist within a wide range of habitats, this demonstrates they should continue to be viewed as a serious threat to wildlife conservation in Florida. Continued action to remove tegus wherever found as part of an early detection/rapid response program, and efforts to educate the public should be a priority for state and federal agencies. In addition, considerations should be made to restrict tegu ownership, breeding and importation into Florida and other states that have subtropical climates and mild winters. Prevention is the most ecologically and economically cost effective approach to combating the introduction of invasive species (Harvey and Mazzotti 2014).

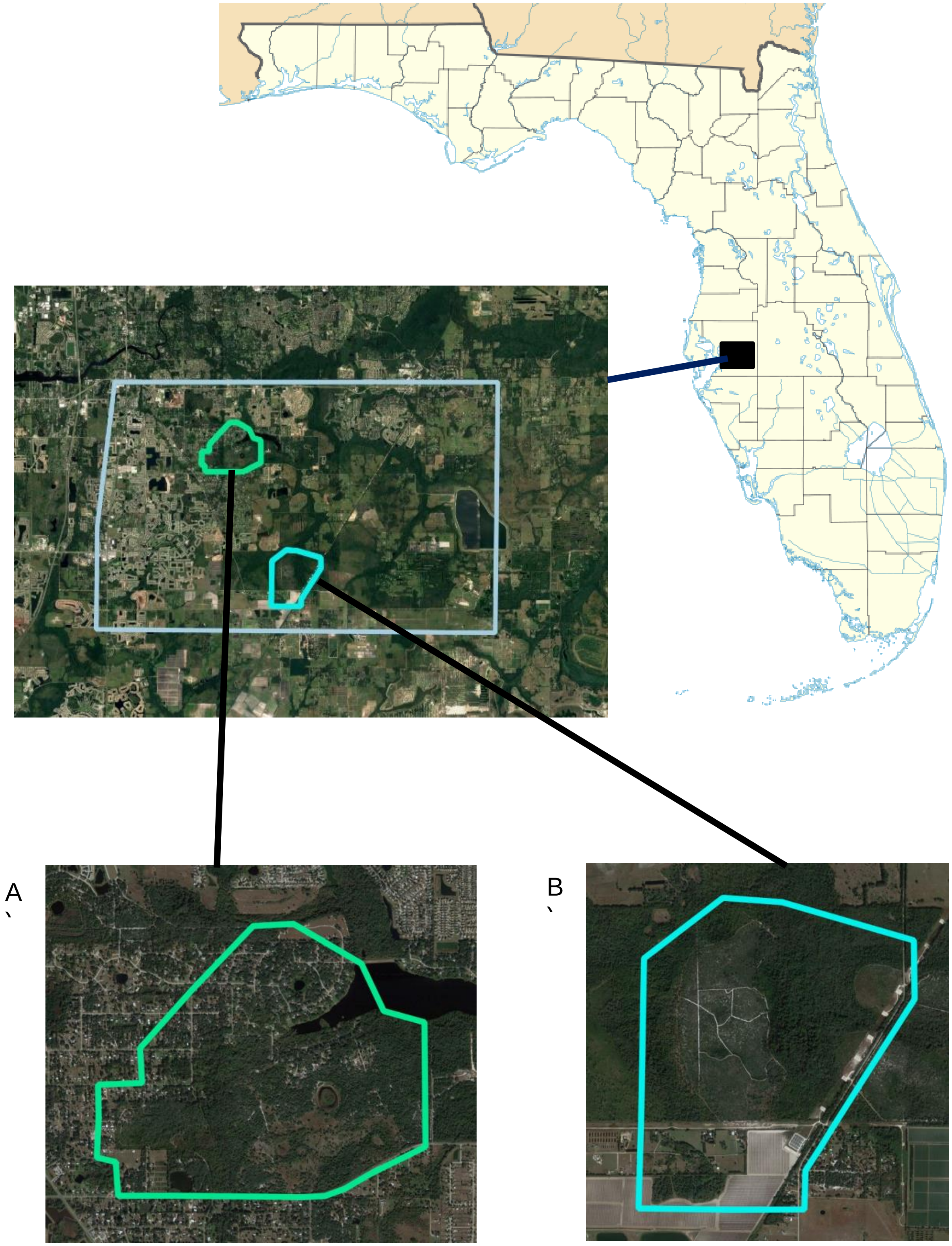


Figure 2-1. Location of study sites in Hillsborough County, Florida including Rhodine Scrub in the north (A) and Balm Boyette Scrub in the south (B). Map data: 2017 Google Maps.

Table 2-1. Tegu identification number; study site in Hillsborough County, Florida from which they were collected: Balm Boyette Scrub (BBS) or Rhodine Scrub (RS), sex of tegu and size at capture.

Tegu ID	Study Site	Sex	Weight at capture (g)	Total Length at capture (cm)
TL1	BBS	F	1200	83.8
TL2	BBS	M	1500	88.9
TL3	BBS	M	1500	91.4
TL4	BBS	M	2300	106.4
TL5	BBS	M	1950	102.2
TL6	BBS	F	790	70.6
TL7	BBS	F	1550	90.8
TL8	BBS	F	1500	95.9
TL9	RS	F	1900	81.1
TL10	RS	F	1950	100.8
TL11	RS	M	2100	102.4
TL12	BBS	F	1100	84.2

Table 2-2. Number of locations recorded for each tegu each season.

	Spring 2015	Summer 2015	Fall 2015	Winter 2015	Spring 2016	Summer 2016	Fall 2016
TL3	3	19	-	-	-	-	-
TL4	6	17	22	14	29	5	7
TL5	-	10	-	-	-	-	-
TL7	-	17	29	14	18	13	2
TL8	-	9	-	-	-	-	-
TL9	-	-	16	12	-	-	-
TL10	-	-	-	13	21	-	1
TL11	-	-	12	-	21	18	-
TL12	-	-	-	-	-	16	6

Table 2-3. Bi-weekly mean temperatures in Riverview, Florida near tegu study sites from October 4th, 2015 through the week of February 21st, 2016. Temperature data obtained from https://www.ncdc.noaa.gov/cdo-web/.

	Temperature (°C)		
Start Date	Max	Avg	Min
October-4	27	25	23
October-18	26	24	23
November-1	27	26	24
November-15	24	22	18
November-29	24	21	19
December-13	25	22	15
December-27	23	20	15
January-10	19	14	10
January-24	21	16	9
February-7	18	15	12
February-21	20	18	13

Table 2-4. Total tegu home range size in hectares (100% minimum convex polygon) for each season, total hectares of each habitat within each tegu's MCP and number of relocations in each habitat type

				100% MCP Home Ranges (hectares) and Recorded Points			
Tegu ID (Study Site)	Year	Season	Total	Wetlands		Urban	
TL3 (BBS)	2015	Fall	7.189	NA	-	0.412	2
TL4 (BBS)	2015	Spring	11.866	0.112	1	1.951	1
		Summer	5.093	NA	-	0.134	1
		Fall	5.916	NA	-	1.330	5
	2016	Spring	41.416	0.598	1	3.139	4
		Summer	0.577	NA	-	NA	-
		Fall	5.594	NA	-	0.100	1
TL5 (BBS)	2015	Summer	3.819	NA	-	NA	-
TL7 (BBS)	2015	Summer	67.850	1.432	-	9.222	1
		Fall	10.722	0.400	1	1.577	17
	2016	Spring	6.465	NA	-	0.703	4
		Summer	16.683	0.464	1	0.761	1
TL8 (BBS)	2015	Summer	3.358	NA	-	NA	-
TL9 (RS)	2015	Fall	3.671	NA	-	0.633	12
TL10 (RS)	2015	Fall	1.270	NA	-	NA	-
	2016	Spring	7.313	3.835	11	0.017	-
TL11 (RS)	2016	Spring	144.937	22.501	3	76.183	5
		Summer	7.022	0.383	-	6.317	11
TL12 (BBS)	2016	Summer	0.335	NA	-	NA	-
		Fall	3.630	NA	-	NA	-

Table 2-4. Continued

100% MCP Home Ranges (hectares) and Recorded Points									
Rural		Scrub		Pasture/ Rangeland		Upland Forest		Utilities	
2.832	6	2.010	2	NA	-	0.178	1	1.757	8
NA	-	8.560	2	NA	-	0.210	-	1.033	2
1.642	4	NA	-	0.347	1	0.283	-	2.686	7
0.898	1	0.176	-	NA	-	0.269	4	3.244	15
4.116	9	25.177	6	1.034	-	3.426	1	3.926	8
NA	-	0.032	1	NA	-	0.120	1	0.426	4
NA	-	4.998	6	NA	-	0.112	-	0.384	-
0.067	1	1.096	1	NA	-	0.896	-	1.761	7
6.906	4	35.605	3	1.836	1	8.143	3	4.706	5
0.470	2	4.142	3	NA	-	1.195	1	2.939	5
1.628	7	0.347	-	0.191	-	0.380	-	3.216	5
0.500	3	6.581	-	NA	-	6.697	2	1.681	4
NA	-	3.358	9	NA	-	NA	-	NA	-
2.068	4	0.346	-	0.455	-	0.169	-	NA	-
NA	-	0.190	9	NA	-	1.080	3	NA	-
NA	-	0.129	6	NA	-	3.332	2	NA	-
11.246	-	19.191	5	1.475	-	14.342	8	NA	-
NA	-	0.025	-	NA	-	0.296	7	NA	-
NA	-	0.335	16	NA	-	NA	-	NA	-
NA	-	3.630	6	NA	-	NA	-	NA	-

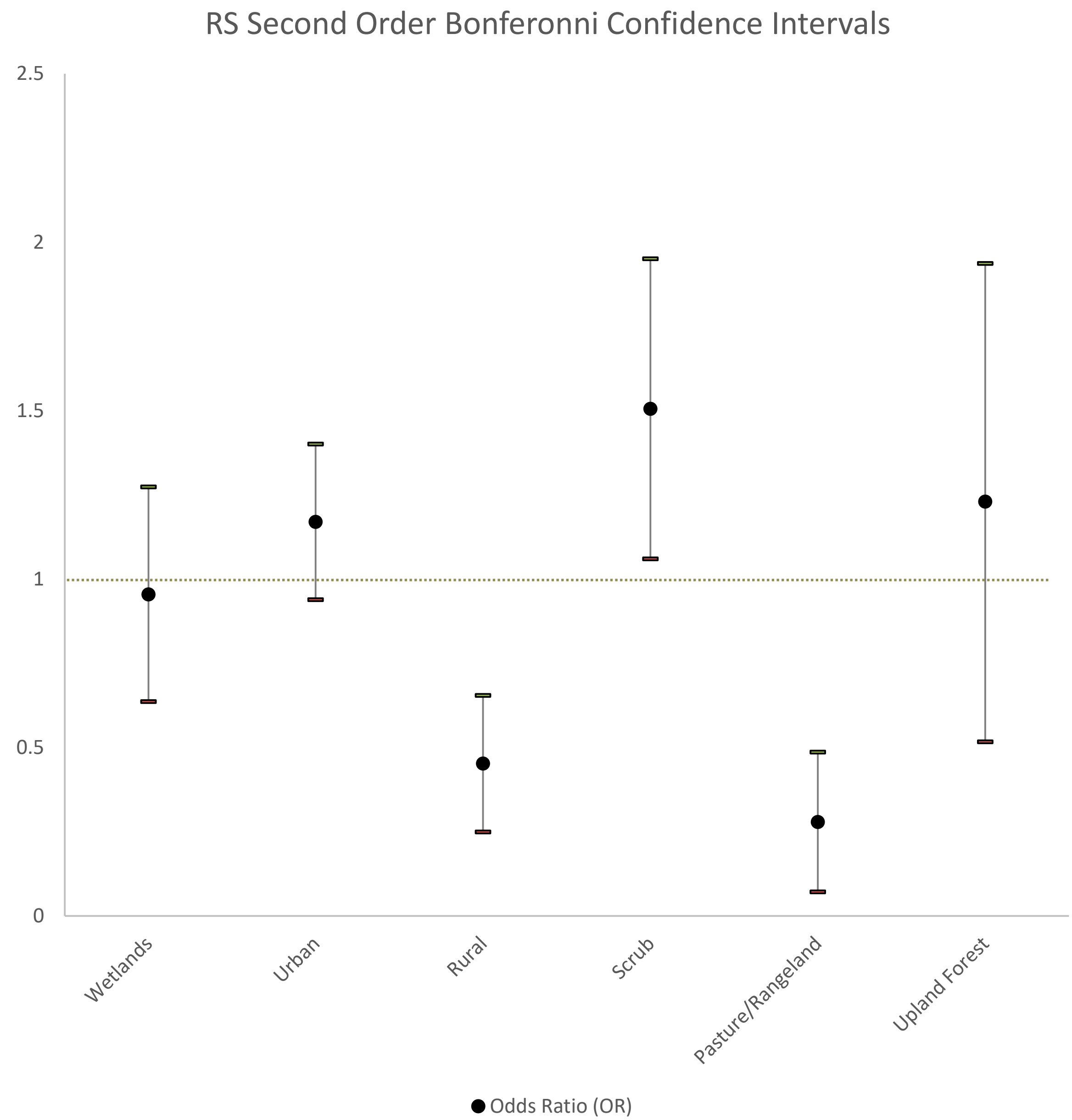


Figure 2-2. Odds ratios (OR) with Bonferroni confidence intervals calculated for tegu second order habitat selection at Rhodine Scrub, Hillsborough County, FL. Intervals greater than 1 (dotted line) indicate selection for a particular habitat type and intervals below one indicate avoidance.

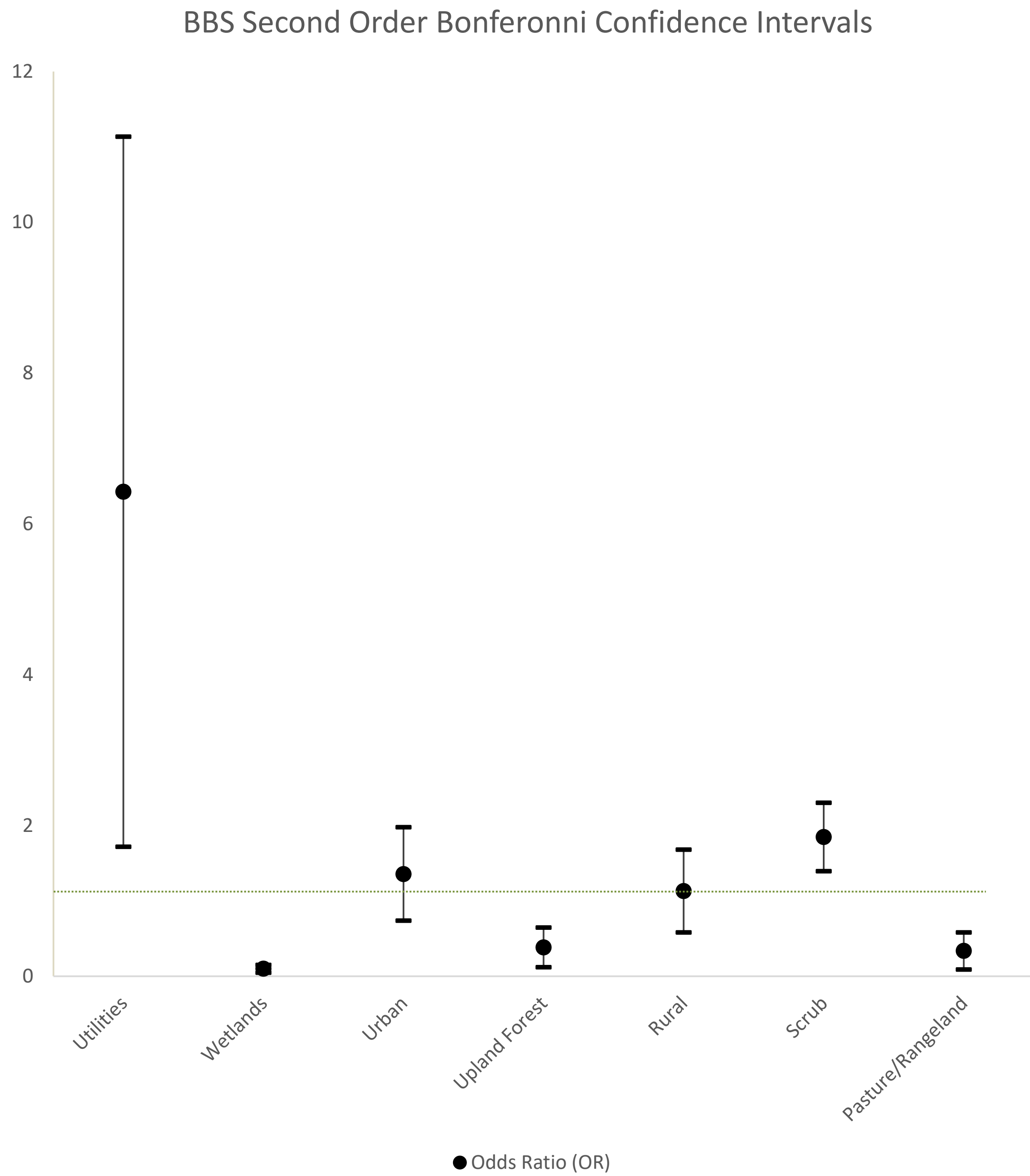


Figure 2-3. Odds ratios (OR) with Bonferroni confidence intervals calculated for tegu second order habitat selection at Balm Boyette Scrub, Hillsborough County, FL. Intervals greater than 1 (dotted line) indicate selection for a particular habitat type and intervals below one indicate avoidance.

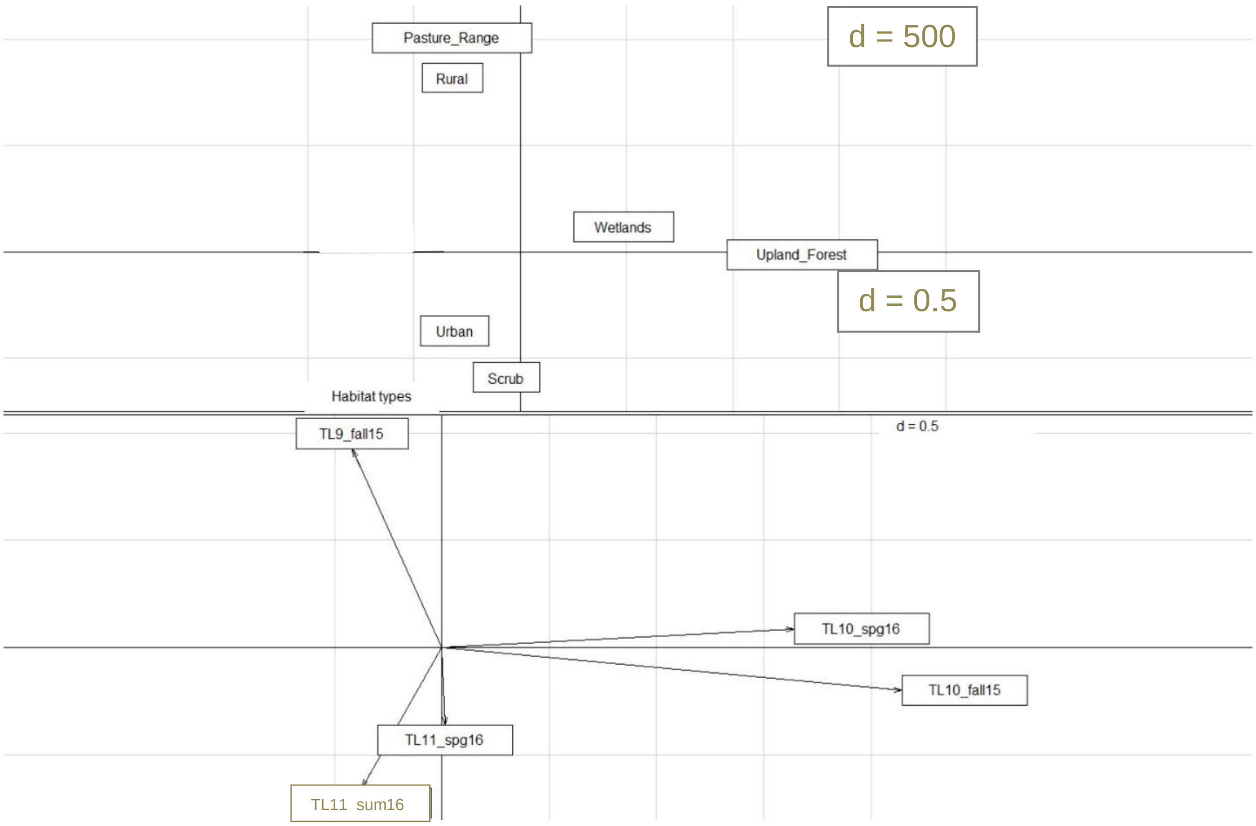


Figure 2-4. Results of Eigenanalysis for tegus within the Rhodine Scrub study site. Factor loading for habitat variables along the first two axes can be seen at the top (distance = 500 units) and marginality vectors for tegus on the factorial plane can be seen at the bottom (distance = 0.5 units). Tegus did not cluster according to habitat, sex, or season.

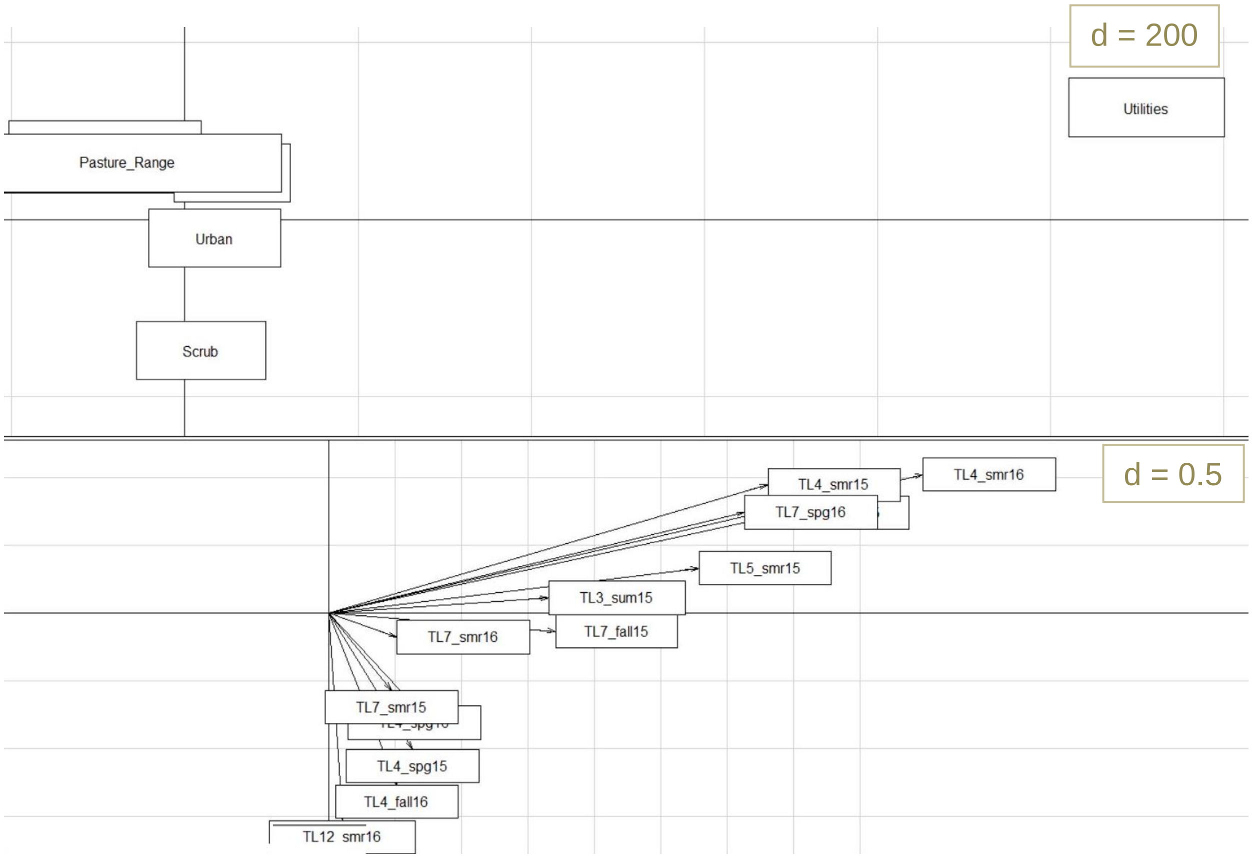


Figure 2-5. Results of Eigenanalysis for tegus within the Balm Boyette Scrub study site. Factor loading for habitat variables along the first two axes can be seen at the top (distance = 200 units) and marginality vectors for tegus on the factorial plane can be seen at the bottom (distance = 0.5 units). Tegus did not cluster according to habitat, sex, or season.

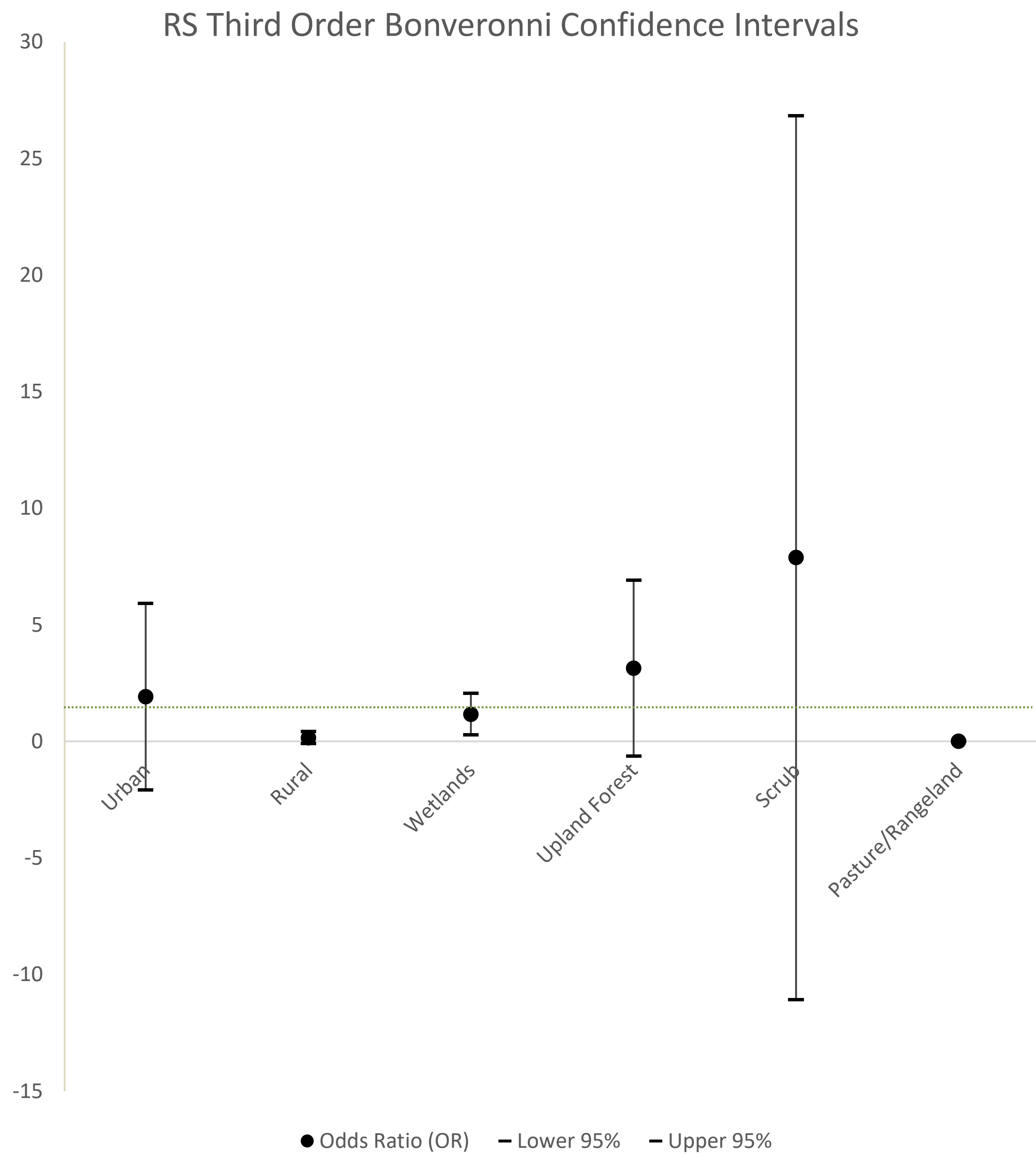


Figure 2-6. Odds ratios (OR) with Bonferroni confidence intervals calculated for tegu third order habitat selection at Rhodine Scrub, Hillsborough County, FL. Intervals greater than 1 (dotted line) indicate selection for a particular habitat type and intervals below one indicate avoidance.

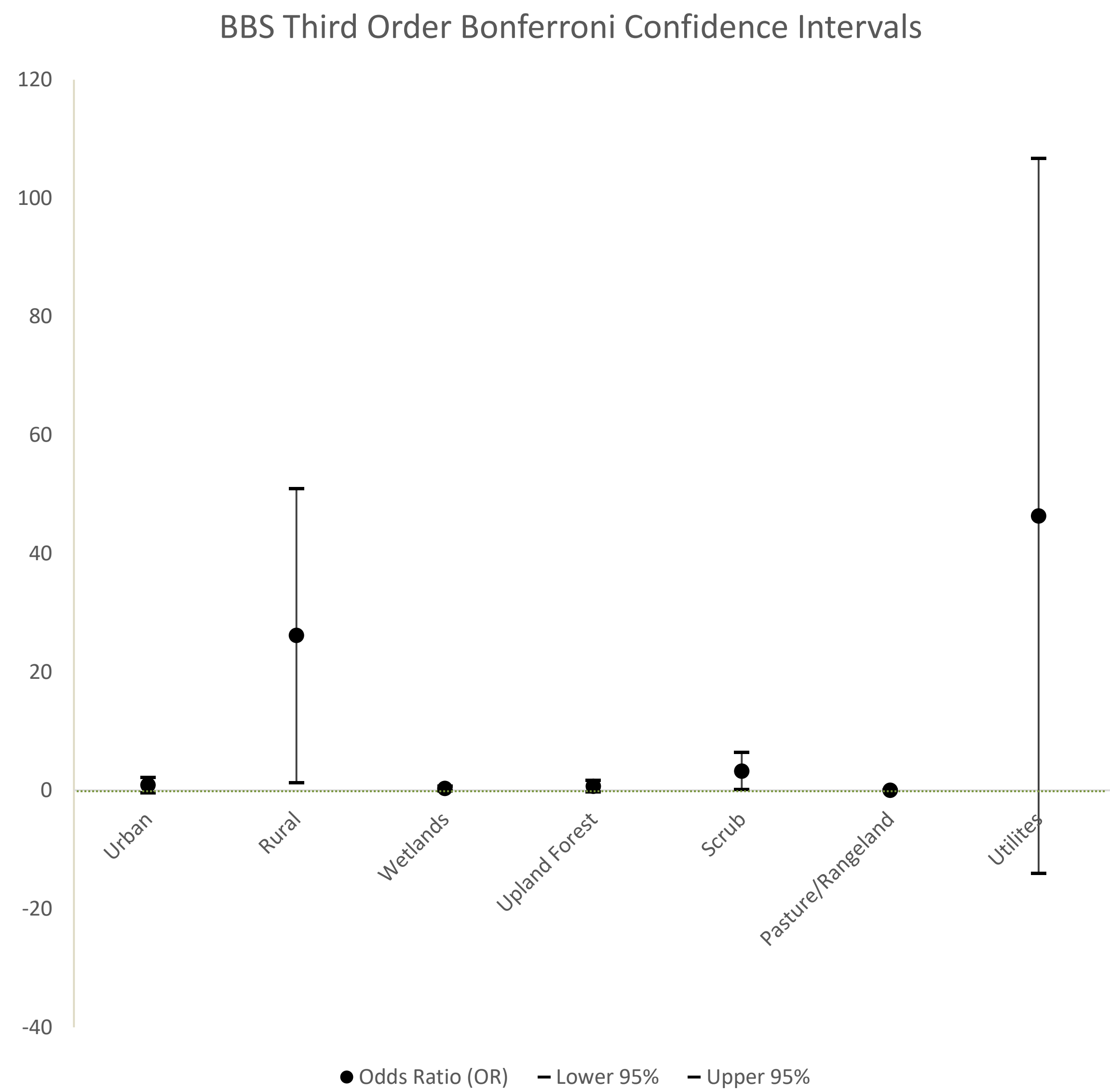


Figure 2-7. Odds ratios (OR) with Bonferroni confidence intervals calculated for tegu third order habitat selection at Balm Boyette Scrub, Hillsborough County, FL. Intervals greater than 1 (dotted line) indicate selection for a particular habitat type and intervals below one indicate avoidance.

CHAPTER 3
DIET OF ARGENTINE BLACK AND WHITE TEGUS IN CENTRAL FLORIDA

Introduction

Invasive species are considered the greatest threat to global biodiversity after habitat loss (Vitousek et al. 1997) and humans have facilitated introductions of non-native species around the globe (Hulme 2009). Introduced predators can be devastating to native wildlife, particularly on islands. In Guam, predation by introduced brown tree snakes (*Boiga irregularis*) resulted in the extirpation of twelve native bird species and a 90% population decline in eight other bird species from parts of the island (Wiles et al. 2003). Introduced cats on Ascension Island resulted in the loss of all but one species of colonial nesting seabirds (Ratcliffe et al. 2009). Even in mainland situations, invasive vertebrates can be extremely problematic to native animals. For example, a study in Everglades National Park, Florida showed that presence of invasive Burmese pythons (*Python bivittatus*) alone explained the decline of marsh rabbits (*Sylvilagus palustris*), a key food resources for a variety of native predators (Sovie et al. 2016) and another study implicated pythons as the reason for decline of raccoon, opossum and bobcat observations during road surveys (Dorcas et al. 2012).

Impacts from invaders may not be apparent for decades after introduction events, allowing time for population establishment and expansion (Simberloff 2013). While there are multiple examples of species decline caused by invasive wildlife and feral animals on islands (Fritts and Rodda 1998, Wiles et al. 2003, Platenberg 2007, Ratcliffe et al. 2009, Bastille-Rousseau et al. 2017) comparatively few exist for mainland ecosystems (Gurevitch et al. 2004). It may not always be possible to disentangle anthropogenic declines from those caused by invasive species, but if human-induced declines are occurring, the presence of an invader could act as an accelerant (Gurevitch et al. 2004). Strategic allocation of limited funds and manpower by agencies tasked with managing the impacts of invaders requires quick and accurate identification of threats to native wildlife from introduced species. To this end, determining the diet of an invasive predator is a first step towards understanding where impacts on native communities might occur.

In Florida, 180 taxa of nonnative herpetofauna (reptiles and amphibians) have been found throughout the state (Krysko et al. 2016). Florida Fish and Wildlife Conservation Commission's (FWC) Wildlife Impacts Management section assesses risks posed by invasive wildlife and FWC has prioritized two snakes and two lizards for removal and continued assessment because of the elevated risk they pose as predators of native wildlife (FWC.com). These high priority species include the Burmese python (*Python molurus bivittatus*), African rock python (*Python sebae*), Nile monitor (*Varanus niloticus*) and Argentine black and white tegu (*Salvator merianae*). All four species are capable of preying upon a diversity of native wildlife including imperiled species (Sovie et al. 2016, Dove et al. 2011, Campbell 2005, Mazzotti et al. 2014).

The Argentine black and white tegu is a large terrestrial Teiid lizard from South America, growing to 145 cm total length and weighing up to 8 kg (Lopez and Abe 1999). This species has a wide native range and occurs in Brazil, Uruguay, Paraguay and Argentina in a variety of habitats (Fitzgerald et al. 1999, Presch 1973). Juvenile tegus are primarily insectivorous, but begin including a variety of vertebrates and fruits in their diet as they age (Mercolli and Yanosky 1994, Colli 1998, Kiefer and Sazima 2002). Two populations of Argentine black and white tegu (ABWT) have been introduced to Florida, one in southern Miami-Dade County and one in west-central Hillsborough County. Tegus in south Florida are well established in and around wetland habitat, whereas in central Florida tegus are primarily concentrated around dry uplands, frequently in scrubby habitats (EDDMapS.org). This contrast implies tegus in south and central Florida may differ substantially in their ecology and impacts on native species.

Scrub ecosystems have a high number of endemic biota and one of the nation's highest concentrations of threatened and endangered species (Scott 2004). Federal and state-listed wildlife that inhabit Florida scrub and surrounding xeric habitats include unique mammals, birds, invertebrates and many terrestrial herpetofauna (Campbell 1992, Humphery 1992, Deyrup 1994). Protected species that could be prey for tegus include the gopher tortoise (*Gopherus polyphemus*), indigo snake (*Drymarchon couperi*), short tailed snake (*Lampropeltis extenuate*), Florida pine snake (*Pituophis melanoleucus*), sand skink (*Neoseps reynoldsi*), gopher frog (*Rana capito*), scrub jay (*Aphelocoma coerulescens*) and the endemic Florida mouse (*Podomys floridanus*) (Campbell 1992, Humphery 1992). Scrub has been highly fragmented and converted to real estate development throughout Florida because of its well-drained soils and relatively high elevation, and over 60 percent of scrub has been lost since the arrival of Florida's first European settlers (Myers 1990, Kautz 1993, Scott 2004). Due to the vulnerability of many scrub species to habitat loss, it is critical to quickly identify and address threats to this habitat, especially when those threats could directly influence the decline in abundance of imperiled wildlife, such as the gopher tortoise (*Gopherus polyphemus*). As ecosystem engineers, gopher tortoises are a keystone species whose burrows provide shelter for a wide variety of vertebrates and invertebrates (Pike and Mitchell 2013, Kinlaw and Grasmueck 2012).

Currently, knowledge of tegu diets in their introduced Florida range is limited to the population in Miami-Dade County to the south, with scant observations in Hillsborough County and central Florida (Barraco 2014, Mazzotti 2014, Enge 2006). The goal of my study was to assess the diet of tegus in central Florida and potentially identify vulnerable scrub species eaten by tegus, thus contributing to the body of knowledge of the risks associated with this invasive lizard in Florida.

Materials and Methods

Study Site

The ABWT population in central Florida is located south of the town of Riverview in eastern Hillsborough County and extends east to the border of neighboring Polk County. It covers a region of 167 km^2 (16,700 hectares) roughly bounded by Bloomingdale Ave to the north, CR 672 in the south, SR 301 to the west and CR 37 to the east, although tegus in Central Florida have been reported beyond this region (Figure 3-1). My study area was determined by historical reports of tegu sightings throughout the region (EDDMapS.org). Natural habitats within the core study area included a matrix of scrub, xeric hammock, upland hardwood forest, hardwood-coniferous forest, mesic flatlands, marshes and freshwater forested and non-forested wetlands. Human-dominated landscapes including urban and rural communities, cropland, rangeland and pasture were scattered among these natural habitats. Tegus collected between May 2012 and September 2016 within this region were included in my diet analysis.

Tegu Acquisition

From May 2012 to September 2016, 105 Argentine black and white tegus were collected from central Florida in Hillsborough County. Tegus came from unpublished studies by the University of Tampa (36 tegus; collected 2012-2013), FWC (43 tegus; collected 2013-2014) and FWC/University of Florida (26 tegus; collected 2015-2016). I acquired 71 tegus from live trapping on a number of properties including 30 tegus from a single 40-acre property situated between two county preserves. Residents in the local community donated 30 tegus removed from private property by live trapping or lethal force. An additional four tegus were collected as roadkill. Researchers trapped tegus under permits issued by FWC and the University of Florida's Institutional Animal Care and Use Committee (protocol 201508846 for UF/FWC collection in 2015-2016). Traps were baited with whole, raw chicken eggs, set in the morning and checked within 24 hours. All bycatch (e.g. raccoons, opossums) was immedialty released on site. I placed traps near gopher tortoise burrows, wildlife trails or other locations where tegus were known to visit. I placed traps in bushes, or provided shade by covering traps with dried palmetto fronds and Spanish moss and provided water in the traps. Euthanasia was performed with CO_2 (University of Tampa collection) or captive bolt (FWC and UF collections).

Diet Analysis

Morphological data I collected for tegus included snout-vent length, tail length, mass and reproductive status. Stomachs were removed from dissected tegus and emptied into glass bowls (UT) or fine mesh sieves (FWC/UF) and washed. I separated stomach contents and identified and counted species eaten. I used unique features of stomach contents (e.g., number of limbs, mouth parts, wings or seeds) where possible to count multiple individuals of one species, but when this was not possible I assumed a single individual. I assumed bird feathers and mammal fur to be from one individual unless multiple species could be confirmed though detailed identification. Feathers were identified to Order using methods described by Dove and Koch (2010) in which feathers are fixed to slides, examined under a light microscope for diagnostic characteristics of the downy barb and compared to characteristics of known species. Guard hairs were used to identify mammals to Order or species using methods described in Debelica and Thies (2009) in which hairs are fixed to a slide, examined under a light microscope for diagnostic characteristics of the medulla and cuticular scale and compared to examples from known species. Although literature suggests tegus sometimes eat ants (Colli et al. 1998), I did not include ingested ants in my diet analysis. Tegus likely ingested ants inadvertently when eating bait or scavenged fruits and so I excluded them. Likewise, small beetles (<5mm), which were found in association with partially digested amphibians and identified in the stomachs and intestinal tract of whole ingested amphibians, were not considered as tegu prey. I recorded incidental ingestion of plant fibers (dried leaves, grasses and sticks) and inorganic items but did not count or include them in final analyses. I calculated frequency of occurrence (FO) and niche overlap (O_{jk}) on the number (not mass) of species consumed. As mentioned, I excluded ants and plant fibers to avoid inaccurate analysis of prey consumption. For similar reasons I did not include the contents of intestinal tract in my diet analysis since some organic parts (e.g., exoskeletons, seeds) can be passed as solid pieces, whereas other parts (e.g., bones, fruit) are partially or fully digested and unrecognizable in the intestine.

Ontogenetic dietary shifts have been documented in tegus in their native range (van Leeuwen et al. 2011), so to calculate the overlap in diet of Central Florida tegus varying in reproductive state and sex, I used Pianka's measure of niche overlap:

$$O_{jk} = \frac{\sum_{n=1} P_{ij}\, P_{ik}}{\sqrt{\sum_{i=1}^{n} P_{ij}^2 \sum_{i=1}^{n} P_{ik}^2}}$$

where P_{ij} is the proportion of item i in group j and P_{ik} is the proportion of item i in group k. The value of O_{jk} ranges between 0 (no overlap) and 1 (complete overlap). I grouped tegus as adults or juveniles, and males and females.

Results

Diet Composition

I collected the stomach contents of 49 male, 48 female and 8 undetermined tegus, with most tegus acquired during the spring and summer months (Figure 3-2). These included 57 reproductive adults and 39 juveniles, determined at time of necropsy, with 9 specimens of undetermined age class. Tegus measured between 10cm and 81.6cm snout-vent length (mean=31.62cm ± 8.86, median=38.5cm) and weighed 20g to 3990g (mean=1342.59g ± 847.85, median=2150g). Out of 105 tegus analyzed, only 12 had empty stomachs. Stomach contents were often digested to one degree or another, but could reliably be identified to at least Order level (Table 3-1).

A total of 103 unique prey items were identified with 34 identified to species. Appendix 1 contains a list of all identified diet components, including inorganic items. Tegus ate a wide variety of taxa including invertebrates and their eggs, vertebrates, bird and reptile eggs, and fruiting bodies of a variety of plants. Individual food items counted in tegu stomachs (n = 93) were comprised of 48% fruits and fruiting bodies, 37%

invertebrates and 15% vertebrates. However frequency of occurrence (FO) of these broad diet groups differed substantially; 51.61% of tegus consumed fruits, 84.95% consumed invertebrates and 80.65% consumed vertebrate prey. When grouped by season, FO of fruit, invertebrates and vertebrates varied (Figure 3-3). Fruit and invertebrate consumption was greatest in summer (fruit: FO = 59.1%; invertebrate: FO = 93.2%) and vertebrate consumption was greatest in the spring (FO = 96.2%).

Fruits were eaten by fewer tegus than vertebrates or invertebrates, although a wide variety of fruits were consumed. Small berries were eaten more frequently than larger fruiting bodies, accounting for the high percentage of individual food items contributed by fruits. Fruits from the genus *Vaccinium* (blueberries) in the Order Ericales accounted for nearly 45% of all individual fruits consumed by tegus and had the highest frequency of occurrence (FO = 15.05%), even though ten taxa of recognizable fruiting bodies were identified. The two most common Orders of fruits consumed after Ericales were Rosales (blackberries, cherries and strawberries; FO = 12.90%) and Arecales (palm drupes; 11.83%). Other fruits were less common (FO < 5%) including Vitales (grapes), Lamiales (lantana and beauty berries), Sapindales (hog plum and citrus), and Solanales (tomatoes). One tegu ate a mass of pelleted grain (animal feed), and acorns were occasionally found along with dried oak leaves, but were considered incidental due to the high frequency which they occurred in the environment but few records from tegu stomachs.

Vertebrates were a conspicuous part of tegu diets at my study site. The remains of hatchling gopher tortoises (*Gopherus polyphemus*), an imperiled species, were found in the stomach contents of five tegus (FO = 5.38%). Other reptiles consumed included snakes and their eggs, such as adult black racers (*Coluber constrictor*) (FO = 13.98%). Lizards (FO = 9.68%) such as brown anoles (*Anolis sagrei*) and eastern fence lizards (*Sceloporus undualtus*) were also eaten. Identifiable amphibians included frogs from families Ranidae (FO = 1.08%), Hylidae (FO = 7.53%) and Bufonidae (FO = 15.05%). Mammals consumed by tegus were primarily from Order Rodentia (rats and mice; FO = 26.88%) but not all fur was able to be identified (FO = 19.35%). Other Orders identified at low frequency (<5%) included Lagomorpha (rabbits), Carnivora (raccoons and skunks), Soricomorpha (moles), Cingulata (armadillos) and Didelphimorphia (opossums). Birds and bird eggs were found in 12 tegus (FO = 12.90%) and three feathers were identified from three orders including Galliformes (chickens and quail), Passeriformes (songbirds) and Falconiformes (falcons and kestrels). A single tegu ate fish (FO = 1.08%) in the form of seven young swamp eels (*Monopterus albus*). Swamp eels are invasive and can be found in lakes and rivers throughout Florida. The finding of swamp eels in this tegu's stomach lead FWC researchers to discover a new, previously undocumented population of swamp eels.

A variety of arthropods were also consumed by the tegus. Stomach contents frequently included arthropods in the Orders Coleoptera (beetles; FO = 59.14) and Orthoptera (grasshoppers and crickets; FO = 52.69%), but also Blattoidia (cockroaches; FO = 17.2%), Hyminoptera and their nests (wasps; FO = 13.98%), Lepidoptera adults and larvae (butterflies and moths; FO = 11.83%), and Araneae (spiders; FO = 6.45%). Two burying beetles of the genus *Nicophorus* were identtified (though not the Federally endangered *N. americanus*). Terrestrial gastropods, both slugs and snails, in the Order Panpulmonata were consumed by nearly a quarter of all tegus (FO = 23.66%). Other invertebrate Orders that were consumed less frequently (<5%) included Dermaptera (earwigs), Diplopoda (millipedes), Chilopoda (centipedes), Diptera (flies and fly larvae), Hemiptera (stink bugs), Homoptera (cicadas), Isopoda (pillbugs), and Decapoda (crayfish).

Niche Overlap

The proportions of food items in the diets of adult and juvenile tegus was not significant enough to identify an ontogenetic shift in diet. Pianka's measure of niche overlap showed adult (n = 57) and juvenile (n = 39) tegus had near complete overlap (O_{jk} = 0.98). Diet overlap of males (n = 43) and females (n = 43) was less, but still very near complete (O_{jk} = 0.95).

Discussion

Understanding the diet of invasive wildlife is crucial to predicting impacts they may have in a new environment, especially when they occur in habitat managed for imperiled species. Although individual food items in tegu diets largely consisted of fruits, many fruits were small berries. Ten individuals accounted for 70% of all fruits consumed among 48 fruit-eating tegus, suggesting that tegus gorge on fruits when available. Fruits are also seasonally abundant which may impact dietary choices. Tegus consumed fruits more frequently in the spring and summer, and less often in the fall (Figure 3-3). Of the study group, 45 tegus (~48%, n = 93) consumed no fruit or plant food items of any kind. A lower frequency of occurrence of vertebrates and invertebrates was also documented in the fall (Figure 3-3), likely because prey species are more active and abundant in the spring and summer months during mating season and seasonal dispersal of young. For these reasons it is important not to overlook the consumption rate of invertebrate and vertebrate animals by tegus.

My result show that tegus in and around scrub habitat are capable of consuming species of concern, namely gopher tortoise hatchlings, but also young and adult snakes. Although no other threatened or endangered species were identified, tegus were found to readily take small mammals, frogs and occasionally birds. Additionally, I was able to document predation by tegus on five invasive species: Cuban tree frog (*Osteopilus septentrionalis*), brown anole (*Anolis sagrei*), swamp eel (*Monopterus albus*), Japanease beetle (*Popillia japonicum*) and the plant lantana (*Lantana camera*). This indicates that tegus may benefit from the presence of other invaders within the environment. Tegus were also shown to take food items that are considered toxic to other wildlife including a variety of caterpillars, lubber grasshoppers (*Romalea microptera*) and lantana. A small number of reptile eggs were documented in tegu stomach contents, however tegus are known to bite holes in eggs and only eat the contents (Milstead 1961, Barraco 2014). Once in the stomach yolk and albumen digest rapidly and become impossible to accurately identify. For this reason it is possible that tegus excavated and consumed eggs of terrestrial wildlife at a frequency greater than I was able to detect in this study.

As documented in other studies, tegus in Hillsborough County eat a wide variety of foods including animal and plant matter (Colli et al. 1998, Mercolli and Yanosky 1998, Barraco 2014). This differs from two other large, invasive, predatory lizards in Florida—the black spiny tailed-iguana (*Ctenosaura similis)* and the Nile monitor (*Varanus niloticus*). Spiny-tailed iguanas in Florida were found to include grasses and flowers as a large component of their diet along with arthropods, with comparatively few vertebrate prey (Krysko et al. 2009). Nile monitors in Florida consume a wide taxonomic range of invertebrate and vertebrate prey, similar to ABWT (Campbell 2005). However, unlike tegus, monitors included aquatic insects in their diet, but few plants or fruits. In South Florida more ABWT consumed gastropods but fewer consume vertebrates compared to tegus at my site (Figure 3-4, Barraco 2014). This may simply be a result of differences in prey availability or innate differences in tegu ecology between the two sites.

When compared to tegus in their home range in Brazil and Argentina, Central Florida ABWTs appear to be eating substantially more invertebrates and vertebrates (Figure 3-4). In all comparisons, Central Florida tegus appear to be including vertebrates as part of their diet more frequently than tegus found elsewhere. The diet identification methods used in my study were very similar to those used by Barraco (2014), though prey identification remains a subjective process to some extent. Additionally time between capture and euthanasia can impact the contents of the stomach, as trapped tegus continue to digest but do not continue to forage. For this reason most tegus in my study were euthanized less than four hours after capture and immediately frozen to preserve stomach contents. Despite these caveats, the trend in consumption of vertebrate prey among central Florida tegus is concerning. There are several explanations that could account for these observations. It is possible I was more thorough in my methods and was able to detect smaller fragments of prey (e.g., a single hair). It could also be that tegus preferentially select for vertebrate prey, and in central Florida small vertebrates are abundant enough that tegus can ignore other available but less desirable food resources. Tegus are a unique predator to the region (e.g. diurnal, terrestrial, large and capable of entering burrows in search of prey), and species may not be adapted to effectively avoid tegu hunting strategies.

Patches of scrub that remain in Hillsborough and surrounding counties in central Florida contain source populations of wildlife that could one day disperse to restored scrub. Tegu presence in Hillsborough County is a direct threat to these species. In healthy scrub and upland environments they may directly and indirectly compete with native wildlife for food, and in habitat presently being restored they may prey upon scrub species as they arrive from dispersal sites. Like islands surrounded by a sea of heterogeneous landscape, it is difficult for endemics to emigrate or immigrate between scrub patches (Liebold 2004, Ricketts 2001). Because tegus are not confined to scrub and can be found throughout the region, they pose an additional risk to species as they travel between these “islands” of scrub.

In addition to threats to wildlife, tegus also have the potential to disperse seeds of domestic and invasive plants. Fruits or drupes of cultivated plants such as strawberries, blueberries, tomatoes, oranges, palms and lantana were found in tegu stomach contents (Appendix 1). Strawberry season beings and ends during the months central Florida tegus are in brumation so it is unlikely tegus would threaten this industry, although blueberries and tomatoes are commercially cultivated in and around the footprint of the central Florida tegu population. Even though tegus were found to consume these crops, domestic cultivars were not found with enough regularity in stomach contents for tegus to be considered agricultural pests.

The diet of Argentine black and white tegus in central Florida is broad and includes a range of taxa from multiple trophic levels. Tegus are capable of consuming threatened and protected scrub species, most notably the gopher tortoise, a keystone species. It is unknown to what extent tegus currently impact scrub fauna in central

Florida, but they have the potential to compromise ongoing restoration efforts. Tegus should be considered a serious threat to native Florida wildlife and efforts should continue to educate public and remove of this large, omnivorous lizard wherever it is found.

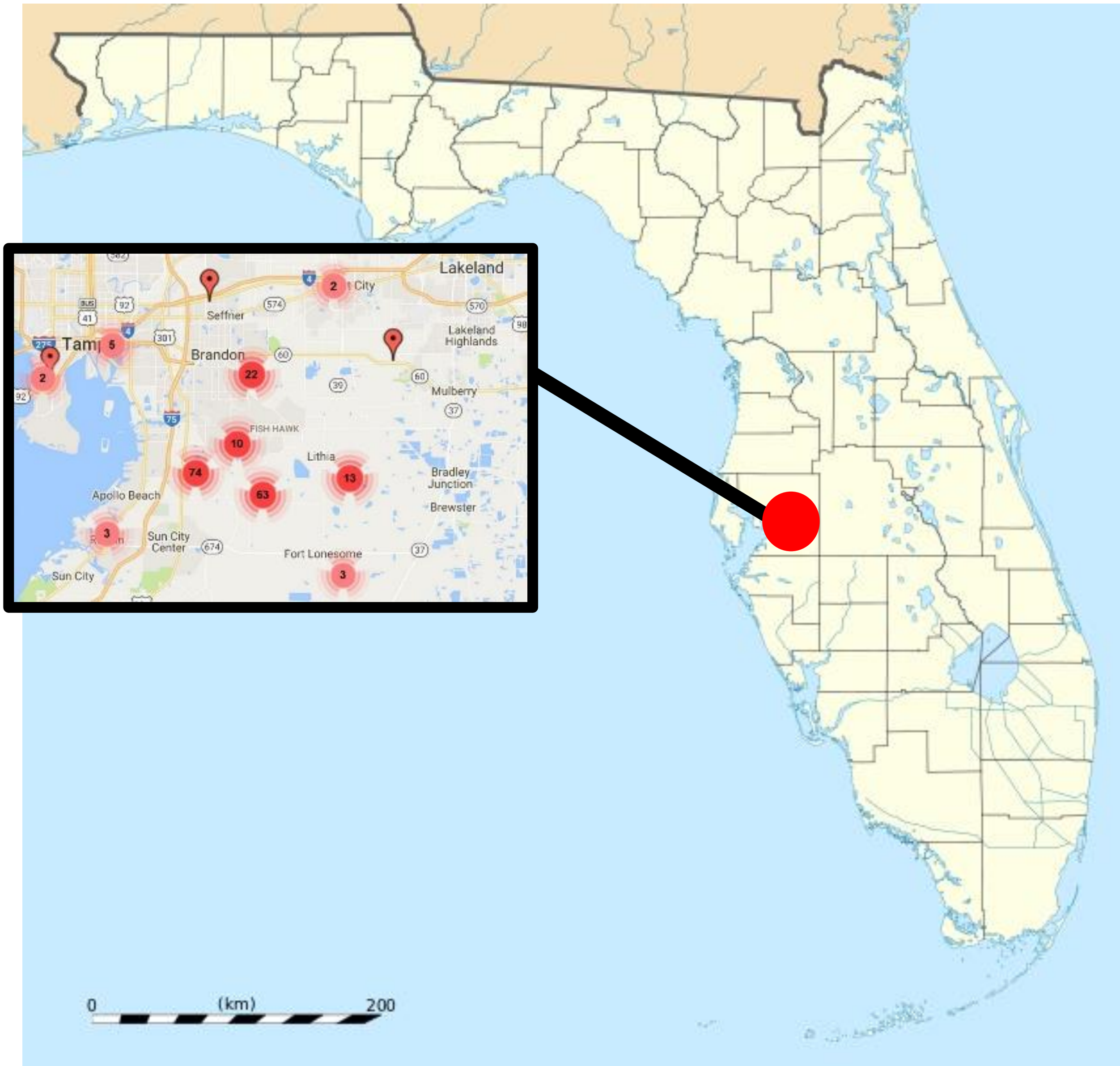


Figure 3-1. Location of Central Florida invasive Argentine black and white tegus (*Salvator merianae*) within Hillsborough County. Numbers appearing in the inset represent credible tegu sightings in the study area. Map data: 2017 Google INEGI.

Table 3-1. Identified Food items consumed by 93 argentine black and white tegus and frequency of occurrence (FO)

Food Item			
Category	Order	Number of Tegus That Consumed Item	FO
Arthropods			
Insecta			
	Blattoidia	16	17.20
	Coleoptera	55	59.14
	Orthoptera	49	52.69
	Hyminoptera	13	13.98
	Lepidoptera	11	11.83
	Dermaptera	1	1.08
	Diplopoda	1	1.08
	Chilopda	2	2.15
	Diptera	4	4.3
	Hemiptera	1	1.08
	Homoptera	3	3.23
Malacostraca	Decapoda	1	1.08
	Isopoda	1	1.08
Arachnid			
	Araneae	6	6.45
Mollusks			
	Panpulmonata	22	23.66
Fish			
	Synbranchiformes	1	1.08
Amphibian			
	Anura (Family Hylidae)	7	7.53
	Anura (Family Ranidae)	1	1.08
	Anura (Family Bufonidae)	14	15.05
	unidentified Anuran	9	9.68
Reptile			
	Squamata (Suborder Lacertilia)	9	9.68
	Squamata (Suborder Serpentes)	13	13.98
	Testudine	5	5.38
	Retile egg	5	5.38
	unidentified reptile	3	3.23

Table 3-1. Continued

Bird			
	Galliformes	1	1.08
	Passeriformes	1	1.08
	Falconiformes	1	1.08
	unidentified	4	4.30
	Bird egg	5	5.38
Mammal			
	Rodentia	25	26.88
	Carnivora	3	3.23
	Lagomorpha	1	1.08
	Soricomorpha	3	3.23
	Artirodactyla	2	2.15
	Didelphimorphia	2	2.15
	unidentified mammal	18	19.35
Plant			
	Ericales	14	15.05
	Rosales	12	12.90
	Solanales	3	3.23
	Vitales	2	2.15
	Lamiales	1	1.08
	Sapindales	3	3.23
	Arecales	11	11.83
	other	14	15.05

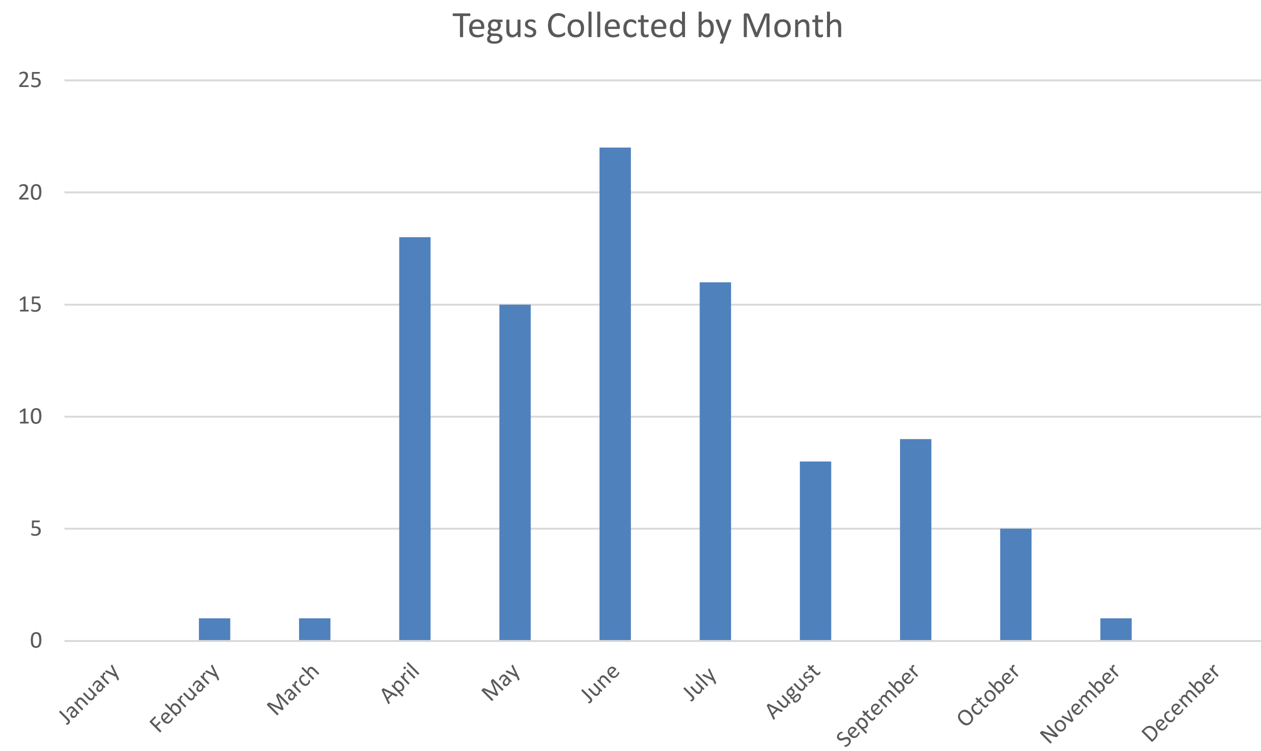


Figure 3-2. Number of tegus collected by month (n = 96)

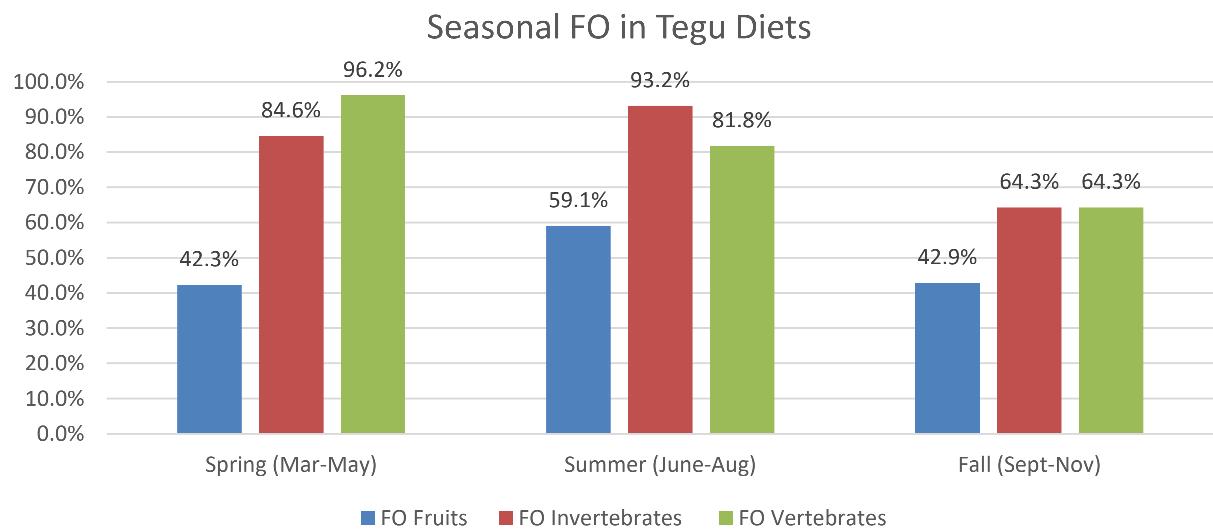
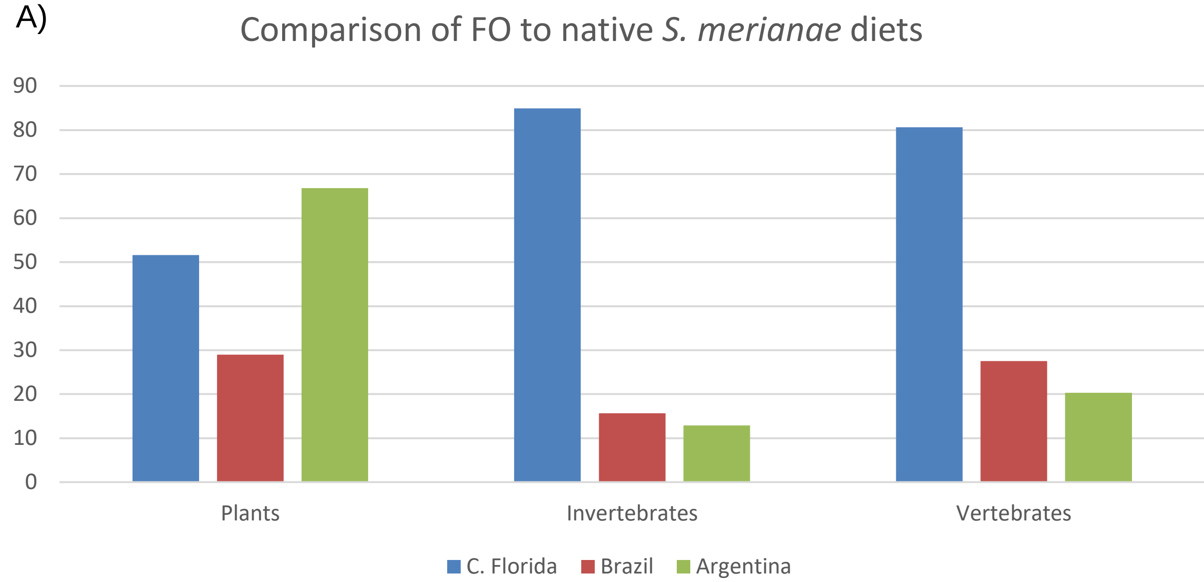


Figure 3-3. Seasonal Frequency of Occurrence (FO) of fruits, invertebrates and vertebrates in invasive *Salvator merianae* in central Florida, expressed as percent (%) of tegus found to have consumed food from each group.

A)



B)

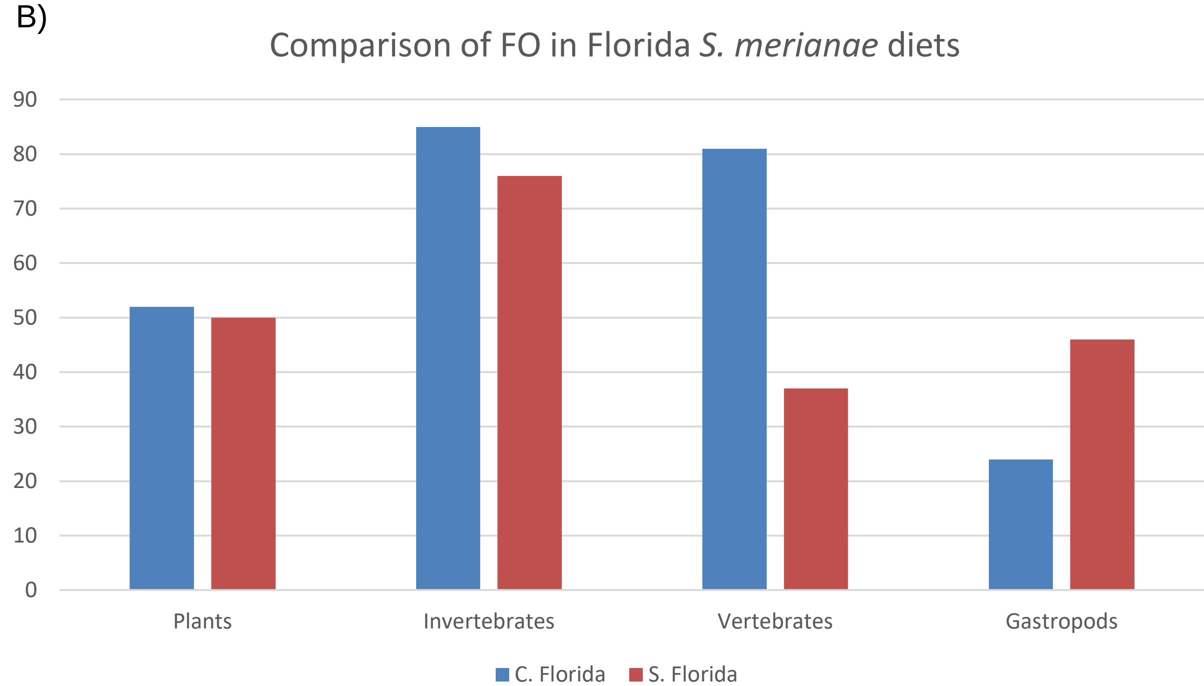


Figure 3-4. Comparison of Frequency of Occurrence (FO) of plants, invertebrates and vertebrates in diets of invasive central Florida *Salvator merianae* to native (A) and introduced (B) populations of *S. merianae.*

CHAPTER 4
CONSERVATION IMPLICATIONS AND CONCLUSIONS

In my study I found tegus to be habitat generalists that consume food from multiple trophic levels. The population of tegus in Central Florida did not strictly associate with one specific habitat type. Instead, habitat selection was variable among individual tegus. Many of these tegus selected for scrub, utilities right-of-ways and urban environments with varying degrees, but generally avoided wetlands and pasture/rangelands. Neither sex nor season influenced habitat selection of tegus. Tegu diets were broad. Tegus ate invertebrates and vertebrates more frequently than fruits. Five tegus were found with the remains of gopher tortoise hatchlings in their stomachs, highlighting the threat tegus pose to imperiled native wildlife. The diets of wildlife are a reflection of habitat selected for foraging, given that habitats are defined by the natural resources found within. In my study, many plant and animal species found in tegu stomach contents are characteristic of scrub and surrounding xeric habitat including fruits from blueberries (*Vaccinium sp*), palmettos (*Serenoa sp*) and grapes (*Vittis sp*) and animals such as the gopher tortoise (*Gopherus polyphemus*), oak toad (*Anaxyrus quercicus*), black racer (*Coluber constrictor*) and golden mouse (*Ochrotomys nuttalli*) (Appendix A, USFWS 1999). This coincides with my findings that tegus select for scrub at second and third order and demonstrates that scrub is a habitat in which tegus acquire food. Tegus consumed a wide variety of taxa such as ground dwelling beetles, rodents, snakes, amphibians and berries. Species from these groups are not restricted to scrub habitat and have a wide distribution in many habitats across Florida which suggests that diet will not restrict tegus to xeric habitats. However, tegus did show selection for scrub habitat and did not select for wetland habitat, indicating they may choose to be in upland habitats for reasons that are not related to diet.

Conclusions drawn from my habitat selection and diet studies may aid land managers in detection and removal of tegus. Vertebrates and invertebrates found in tegu stomachs include many species that are known to associate with gopher tortoise burrows (Christman 1988, Campbell 1992, Humphrey 1992, Deyrup and Franz 1994, Kinlaw and Grasmueck 2012), and tegus encountered traps placed near gopher tortoise burrows during the course of my study. During the radio tracking portion of my habitat selection study, all but two tegus (TL12, TL8) eventually included residential regions in their home range, or had relocations along a boundary between residential and natural areas. Tegus in Central Florida are found in a diverse matrix of habitats that offer no distinct corridor for movement. This means that trap lines are insufficient to ensure trap encounter. For these reasons, when considering management strategies for the removal or control of tegus in upland habitats I recommend focused trapping near gopher tortoise burrows and along urban edges. Where tegu presence has not been confirmed, cameras placed at gopher tortoise burrows can be used to monitor for tegu presence and traps can be deployed if tegus are detected to ensure sensitive wildlife is not put at additional risk.

Although my findings about tegu spatial ecology and diet have contributed to a more robust understanding of tegu presence in Florida, there is much yet to be learned. Because tegus pose an immediate threat to imperiled species, future studies should focus primarily on removal. Although tegus use a variety of habitats, they do not use all habitat in equal proportion. Identification of tegu dispersal and movement corridors would allow agencies to focus trapping efforts and prevent tegus from spreading into new habitat and can be done by outfitting hatchling tegus with telemeter harnesses. Likewise, continued effort can be made to advance trapping success of tegus in Central Florida. Here, movement corridors are ill defined and encounter rate is low in comparison to tegus in South Florida. Pheromones should be explored as a bait alternative and could potentially attract tegus from a greater distance while simultaneously reducing or eliminating bycatch. Efforts should continue for development and implementation of local and state-wide EDRR programs for tegus. In my experience, the public is very receptive to tegu removal efforts. A dedicated trap loan program in central Florida should be created or expanded to increase successful removal of tegus by citizens, an extension of citizen science. Central Florida tegu populations should continue to be monitored. Based on the findings presented in this thesis I recommend that public education as well as monitoring for and removal of tegus continue throughout the state. Finally, the results of my study, data from tegus in southern Florida, and the growing number of records of this species across Florida (e.g., EDDMapS.org), prove this lizard is a current and growing threat to native ecosystem, similar to the situation with Burmese pythons and Nile monitors. Therefore, tegus should be immediately added to the state's list of "conditional snakes and lizards" by the Florida Fish and Wildlife Conservation Commission. These actions are key to preventing future impacts.

APPENDIX
LIST OF ITEMS CONSUMED BY TEGUS

Table A-1. Items consumed by tegus organized by taxa

Phylum or Class	Order	Family	Common Name (Species Name)
Insecta			
	Blattoidea	Ectobiidae	Cockroach
			Cockroach Egg Case
	Coleoptera	Carabidae	Tiger beetle
			Ground beetle, large dark
			Unidentified Ground Beetle (Carabidae)
		Cerambycidae	Longhorn beetle (*Cerambycidae* sp)
		Curculionidae	Snout beetle
		Elateridae	Click beetle
		Passalidae	Bessy beetle
		Scarabaeidae	Scarab beetle, possibly dung beetle
			May Beetle (*Phyllophaga* sp)
			Scarab beetle, small yellow
			Unidentified scarab beetle (Scarabidae)
			Japanease beetle (*Popillia japonicum*)
		Silphidae	Burying beetle (*Nicrophorus* sp)
		Unidentified	Unidentified beetle
			Larval beetle (grub)
	Dermaptera	Unidentified	Earwig
	Diplopoda	Unidentified	Millipede
	Diptera	Sarcophagidae	Fly larvae
		Tabanidae	Large fly (horsefly or soldierfly)
		Unidentified	Unidentified fly (adult)
	Hemiptera	Cicadidae	Unidentified cicada
			Cicada larva
		Lygaeidae	Milkweed bug (*Oncopeltus fasciatus*)
		Pentatomidae	Stink bug
		Unidentified	unidentified planthopper
	Hymenoptera	Crabronidae	Cicada killer (*Sphecius speciousus*)

Table A-1. Continued

Phylum or Class	Order	Family	Common Name (Species Name)
		Formicidae	Ants
		Vespidae	Unidentified wasp
			Paper Wasp (*Polisties* sp))
			Paper Wasp Nest w/Wasps (*Vespidae*)
	Lepidoptera	Geometridae	Inchworm
		Saturniidae	Regal moth (*Citheronia regalis*)
			Moth (*Anisota* sp.)
			Moth (*Agraulis* sp)
		Unidentified	Unidentified moth
			Unidentified caterpillar
	Mantodea	Unidentified	Praying mantis (egg capsule)
	Orthoptera	Acrididae	American birdwing grasshopper (*Schistocerca americana*)
			Short-winged grasshopper (*Dichromorpha viridis*)
			Spur-throated grasshopper
			Band-winged grasshopper
			Shorthorned grasshopper (unidentified)
	Orthoptera	Gryllotalpidae	Mole cricket
	Orthoptera	Romaleidae	Lubber grasshopper (*Romalia microptera*)
	Orthoptera	Tettigoniidae	Katydid (green)
	Orthoptera		Bush cricket
	Orthoptera	Unidentified	Unidentified Grasshopper
	Unidentified		Unidentified insect
Myriapoda			
	Chilopoda	Unidentified	Centipede (green)
	Diplopoda	Unidentified	Millipede
Arachnida			
	Aranae	Lycosidae	Wolf spider
		Salticidae	Jumping spider
		Unidentified	Unidentified spider
Crustacea			
	Isopoda	Armadilidiiae	Pillbug
	Decapoda	Unidentified	Unidentified crayfish

Table A-1. Continued

Phylum or Class	Order	Family	Common Name (Species Name)
Mollusca			
	Gastropoda	Ampullarioidea	Apple snail (*Pomacea*)
		Planorbidae	Unidentified snail
			Ramshorn snail (*Marisa cornuaurietus*)
		Veronicellidae	Florida leatherleaf slug (*Leidyula floridana*)
		Unidentified	Unidentified slugs
Chordata			
	Vertebrata	Unidentified	Unidentified vertebrate bones
Amphibia			
	Anura	Bufonidae	Southern toad (*Anaxyrus terrestris*)
			Oak toad (*Anaxyrus quercicus*)
			Unidentified toad
		Hylidae	Cuban treefrog (*Osteopilus septentrionalis*)
			Green treefrog (*Hyla cinerea*)
			Pinewoods treefrog (*Hyla femoralis*)
			Unidentified treefrog
		Ranidae	Bullfrog (*Rana catesbiana*)
			Unidentified true frog
		Scaphiopodidae	Spadefoot toad (*Scaphiopus holbrookii*)
Reptilia			
	Squamata	Anguidae	Eastern glass lizard (*Ophisaurus ventralis*)
		Colubridae	Black racer (*Coluber constrictor*)
		Dipsadidae	Ringneck snake (*Diadophis puncatatus*)
		Iguanidae	Fence lizard (*Sceloporus undulatus*)
		Polychrotidae	Cuban brown anole (*Anolis sagrei*)
			Cuban brown anole egg
		Unidentified	Unidentified lizard
			Unidentified snake (vertebrae, skin)
			Unidentified snake eggs

Table A-1. Continued

Phylum or Class	Order	Family	Common Name (Species Name)
	Testudines	Testudinidae	Gopher tortoise (*Gopherus polyphemus*)
		Unidentified	Unidentified turtle eggs
Aves			
	Columbiformes		Dove sp
	Falconiformes		Hawk sp
	Galliformes		Quail sp
	Passeriformes		Songbird sp
	Unidentified		Unidentified bird (whole or parts)
			Unidentified bird eggs
Mammalia			
	Carnivora	Procyonidae	Raccoon (*Procyon lotor*)
		Mephitidae	Striped skunk (*Mephitis mephitis*)
	Cingulata	Dasypodidae	Nine banded armadillo (*Dasypus novemcinctus*)
	Didelphimorphia	Didelphidae	Virginia opossum (*Didelphis virginiana*)
	Lagomorpha	Leporidae	Eastern cottontail (*Sylvilagus floridanus*)
	Rodentia		Unidentified rodent
		Cricetidae	Cotton mouse (*Peromyscus gossypinus*)
			Deer mouse (*Peromyscus* sp)
			Golden mouse (*Ochrotomys nuttalli*)
			Marsh rice rat (*Oryzomys palustris*)
			Hispid cotton rat (*Sigmodon hispidus*)
		Muridae	Black rat (*Rattus rattus*)
	Saricomorpha	Talpidae	Eastern mole (*Scalopus aquaticus*)
	Unidentified		Unidentified mammal (hair only)
Actinopterygii			
	Synbranchiformes	Synbranchidae	Asian swamp eel (*Monopterus albus*)

Table A-1. Continued

Phylum or Class	Order	Family	Common Name (Species Name)
Plantae	Arecacae	Arecacae	Saw palmetto (*Serenoa repens*)
			Unidentified palm
	Ericales	Ericaceae	Blueberry (*Vaccinium* sp)
	Lamiales	Vervenaceae	Lantana (*Lantana camara*)
	Rosales	Rosaceae	Wild cherry (*Prunus serotina*)
			Strawberry (*Fragaria ananassa*)
			Blackberry (*Rubus* sp)
	Solanales	Solanaceae	Tomato (*Solanum lycopersicum*)
	Sopondias	Anacardiaceae	Citrus fruits (*Citrus* sp)
			Hog plum (*Spondias mombin*)
	Vitales	Vitaceae	Wild grape (*Vitis* sp)
	Unidentified		Unidentified metallic blue fruit
			Unidentified berries
Incidental			
	Hairs		Horse and human hair
	Plant parts		Unidentified sticks
			Unidentified plant parts
		Poaceae	*Spartina bakeri*
			Unidentified Grass
			Unidentified Grass Seeds
		Quercus	Oak Nuts
			Live Oak Leaves
			Laurel Oak Leaves
			Water Oak Leaves
			Unidentified Oak Flower
		Rosaceae	Haw Leaves (*Crataegus*)
	Inanimate		Inanimate (sand, rocks, fibers, paper, etc.)
	Unidentified		Unidentified mass, blob, etc.
Bait			Chicken Eggs (whole or shell pieces)
			Hotdog Pieces
Parasite	Nematoda		nematodes

LIST OF REFERENCES

Abrahamson, W. G. and D. C. Hartnett. 1990. Pine flatwoods and dry prairies. Pages 103-149 *in* R.L. Meyers, and J.J. Ewel, editors. Ecosystems of Florida. University of Central Florida Press, Orlando, FL.

Baracco, L. A. 2015. Risk Assessment of the Nonnative Argentine Black and White Tegu, *Salvator merianae,* in South Florida. Thesis, Florida Atlantic University, Boca Raton, Fl.

Bastille-Rousseau, G., J. P. Gibbs, K. Campbell, C. B. Yackulic and S. Blake. 2017. Ecosystem implications of conserving endemic versus eradicating introduced large herbivores in the Galapagos Archipelago. Biological Conservation 209:1-10.

Berge, S. 2014. sigloc: Signal Location Estimation. R package version 0.0.4. <https://CRAN.R-project.org/package=sigloc>. Accessed 3 March 2017.

Bomford, M., F. Kraus, S. C. Barry, E. Lawrence. 2008. Predicting establishment success for alien reptiles and amphibians: a role for climate matching. Biological Invasions 11:713-724.

Burnett, K. and B. Kaiser. 2010. Spatial Economic Analysis of Early Detection and Rapid Response Strategies for an Invasive Species. Resource and Energy Economics 32:566-585.

Calenge, C. 2006. The package “adehabitat” for the R software: a tool for the analysis of space and habitat use by animals. Ecological Modelling 197:516-519.

Calenge, C. and A. B. Dufour. 2006. Eigenanalysis of selection ratios from animal radio-tracking data. Ecology 87:2349-2355.

Campbell, H. W. 1992. Pages 150-153 *in* P. E. Moler, editor. Rare and Endangered Biota of Florida, Volume III Amphibians and Reptiles. University Press of Florida, Gainesville, FL.

Campbell, TS. 2005. Eradication of introduced carnivorous lizards from the Cape Coral area. Final Report to the Charlotte Harbor National Estuary Program, Fort Meyers, FL.

Christman, Steven P. 1988. Endemism and Florida's interior sand pine scrub. Final project report to Florida Game and Freshwater Fish Commission. Tallahassee, FL.

Colli, G. R., A. K. Peres, and H. J. Cunha. 1998. A new species of *Tupinambis*: (Squamata: Teiidae) from Central Brazil, with an analysis of morphological and genetic variation in the genus. Herpetologica 54:477-492.

Courchamp, F., J. L. Chapuis and M. Pascal. 2002. Mammal invaders on islands: impact, control and control impact. Biological Review 78:347-383.

Deyrup, M. and R. Franz, editors. 1994. Rare and Endangered Biota of Florida Volume 4: Invertebrates. University Press of Florida, Gainesville, FL.

Dorcas, M. E., J. D. Willson, R. N. Reed, R. W. Snow, M. R. Rochford, M. A. Miller, W. E. Meshaka, Jr., P. T. Andreadis, F. J. Mazzotti, C. M. Romagosa and K. M. Hart. 2012. Severe mammal declines coincide with proliferation of invasive Burmese pythons in Everglades National Park. PNAS 197: 2418-2422.

Dove, C. J., R. W. Snow, M. R. Rochford, and F. J. Mazzotti. 2011. Birds consumed by the invasive Burmese python (*Python molurus bivittatus*) in Everglades National Park, Florida, USA. The Wilson Journal of Ornithology 123:126-131.

Early Detection and Distribution Mapping System (EddMapS). 2017. Black and white tegu. The University of Georgia -Center for Invasive Species and Ecosystem Health. <https://www.eddmaps.org/distribution/viewmap.cfm?sub=82961> Accessed 16 September 2017.

Enge, K., 2006. FWC bioprofile for the Argentine black and white tegu. < https://bugwoodcloud.org/CDN/floridainvasives/TeguBioprofileSep2006.pdf>. Accessed 12 May 2017.

Ferrira, R. B., K. H. Beard, S. L. Peterson, S. A. Poessel, C. M. Callahan. 2012. Establishment of introduced reptiles increases with the presence and richness of native congeners. Amphibia-Reptilia 33:387-392.

Fitzgerald, L. A., J. M. Chani, and O. E. Donadío. 1991. Tupinambis lizards in Argentina: implementing management of a traditionally exploited resource. Pages 303-316 *in* J. G. Robinson and K. H. Redford, editors. Neotropical Wildlife: Use and Conservation. University of Chicago Press, Chicago, Illinois.

Fitzgerald, L. A., F. B Cruz, and G. Perotti. 1993. The Reproductive Cycle and the Size at Maturity of *Tupinambis rufescens* (Sauria: Teiidae) in the Dry Chaco of Argentina. Journal of Herpetology 27:70-78.

Florida Fish and Wildlife Conservation Commission (FWC). 2017. American burying beetle: *Nicrophorus americanus*. <http://myfwc.com/media/2211649/America-%20burying-beetle.pdf>. Accessed 13 September 2017.

Florida Natural Areas Inventory (FNAI). 2010. Guide to the Natural Communities of Florida. <http://fnai.org/PDF/FNAI-Natural-Community-Classification-Guide-2010_20150218.pdf>. Accessed 10 May 2017.

Fritts, T. H. and G. H. Rodda. 1998. The role of introduced species in the degradation of island ecosystems: a case history of Guam. Annual Review of Ecological Systems 29:113-140

Fujisaki, I., K. M. Hart, F. J. Mazzotti, K. G. Rice, S. Snow, and M. Rochford. 2010. Risk assessment of potential invasiveness of exotic reptiles imported to South Florida. Biological Invasions 12:2585-2596.

Gilbert, F., A. Gonzalez, and I. Evans-Freke. 1998. Corridors maintain species richness in the fragmented landscapes of a microecosystem. Proc. R. Soc. London Ser. B, 265:577–582.

Gonzalez, A. and E.J. Chaneton. 2002. Heterotroph species extinction, abundance and biomass dynamics in an experimentally fragmented microecosystem. Journal of Animal Ecology 71:594–602.

Gurevitch, J. and D. K. Padilla. 2004. Are invasive species a major cause of extinctions? TRENDS in Ecology and Evolution 19:470-474.

Harvey, R. and F. Mazzotti. 2104. The invasion curve: a tool for understanding invasive species management in south Florida," University of Florida IFAS, <https://edis.ifas.ufl.edu/pdffiles/UW/UW39200.pdf>. Accessed 9 September 2017.

Hillsborough County Parks, Recreation and Conservation Department, 2011. Protecting our Environmentally Sensitive Lands and Wildlife. <http://www.hillsboroughcounty.org/library/hillsborough/media-center/documents/conservation-and-regional-parks/elapp/elapp-brochure.pdf>. Accessed 23 September 2017.

Hulme, P. E. 2009. Trade, Transport, and Trouble: Managing Invasive Species Pathways in an Era of Globalization. Journal of Applied Ecology 46:10-18.

Humphrey, S. R., editor. 1992. Florida Mouse. Pages 250-263 *in* Rare and Endangered Biota of Florida, Volume I. Mammals, University Press of Florida, Gainsville, FL. IUCN. 2017. *Salvator merianae.* <http://www.iucnredlist.org/details/178340/0>. Accessed 10 July 2017.

Johnson, D. H. 1980. The comparison of usage and availability measurements for evaluating resource preference. Ecology 61:65-71

Juri, G. L., S. Naretta, A. C. Mateos, M. Chiaraviglio, and G. Cardozo. 2015. Influence of life history traits on trophic niche segregation between two similar sympatric *Tupinambis* lizards. South America Journal of Herpetology 10:132-142.

Kaiser, B. 2016. Final report on Cooperative Agreement No. 40181AJ085 (30 March 2010 – 31 October 2015). Final report to US Fish and Wildlife Service. Hillsborough County, FL

Kamath, A., Y. E. Stuart, and T. S. Campbell. 2013. Behavioral partitioning by the native lizard *Anolis carolinensis* in the presence and absence of the invasive *Anolis sagrei* in Florida. Breviora 535:1-10.

Kautz, R.S. 1993. Trends in Florida wildlife habitat 1936-1987. Florida Scientist 56:7-24.

Kay, S. L., J. W. Fischer, A. J. Monaghan, J. C. Beasley, R. Boughton, T. A. Campbell, S. M. Cooper, S. S. Ditchkoff, S. B. Hartley, J. C. Kilgo, S. M. Wisely, A. C. Wychoff, K. C. VerCautereen, and K. M. Pepin. 2017. Quantifying drivers of wild pig movement across multiple spatial and temporal scales. Movement Ecology 5:1-15.

Kiefer, M. C., and I. Sazima. 2002. Diet of Juvenile Tegu Lizard *Tupinambis merianae* (Teiidae) in Southeastern Brazil. Amphibia-Reptilia 23:105-108.

Kier, G., H. Kreft, T. M. Lee, W. Jetz, P. L. Ibisch, C. Nowicki, J. Mutke and W. Barthlott. 2009. A global assessment of endemism and species richness across island and mainland regions. PNAS 106:9322-9327

King, D., B. Green, and E. Herrera. 1994. Thermoregulation in and large Teiid lizard, *Tupinambis teguixin*, in Venezuela. Copeia 1994:806-808.

Kinlaw, A. and M. Grasmueck. 2012. Evidence for and geomorphologic consequences of a reptilian ecosystem engineer: the burrowing cascade initiated by the Gopher Tortoise. Geomorphology 158:108-121.

Klug, P. E., R. N. Reed, F. J. Mazzotti, M. A. McEachern, J. J. Vinci, K. K. Craven and A. A. Yakckel Adams. 2014. The influence of disturbed habitat on the spatial ecology of Argentine black and white tegu (*Tupinambis merianae*), a recent invader in the Everglades ecosystem (Florida, USA). Biological Invasions 17:1785-1797.

Krysko, K. L., K. W. Larson, D. Diep, E. Abellana, and E. R. McKercher. 2009. Diet of the nonindigenous black spiny-tailed iguana, *Ctenosaura similis* (Gray 1831) (Sauria: Iguanidae), in southern Florida. Biological Sciences 72:48-58.

Krysko, K. L., L. A. Somma, D. C. Smith, C. R. Gillette, D. Cueva, J. A. Wasilewski, K. M. Enge, S. A. Johnson, T. S. Campbell, J. R. Edwards, M. R. Rochford, R. Tompkin, J. L. Fobb, S. Mullin, C. J. Lechowicz, D. Hazelton and A. Warren. 2016. New verified nonindigenous amphibians and reptiles in Florida through 2015, with summary of over 152 years of introductions. IRCF Reptiles & Amphibians 23:110-143.

Lekevicius, E. 2009. Vacant niches in nature, ecology and evolutionary theory: a mini-review. Ekologija 55:165-174.

Liebold, M. A., M. Holyoak, N. Mouquet, P. Amarasekare, J. M. Chase, M. F. Hoopes, R. D. Holt, J. B. Shurin, R. Law, D. Tilman, M. Loreau, and A. Gonzalez. 2004. The metacommunity concept: a framework for multi-scale community ecology. Ecology Letters 7:601-613.

Lockwood, J., M. F. Hoopes, and M. P. Marchetti. 2013. Invasion Ecology Second Edition. Wiley-Blackwell, West Sussex, UK.

Lopes, H. R., and A. S. Abe. 1999. Biologia reprodutivo e comportamento do teiú,

Tupinambis merianae, em cativeiro (Reptilia, Teiidae). Pages 259–272 in T. G. Fang, O. L. Montenegro, and R. E. Bodmer, editors. Manejo y Conservación de Fauna Silvestre en América Latina. Instituto de Ecología, La Paz, Bolivia.

Mahoney, P. J., K. H. Beard, A. M. Durso, A. G. Tallian, A. L. Long, R. J. Kindermann, N. E. Nolan, D. Kinka and H. E. Mohn. 2015. Introduction effort, climate matching and species traits as predictors of global establishment success in non-native reptiles. Diversity and Distributions 21:64-74

Manly, B. F.J., L. L. McDonald, D. L. Thomas, Trent. L. McDonald, and W. Erickson. 2002. Resource selection by animals: statistical analysis and design for field studies. Second edition. Kluwer Academic, Boston, Massachusetts, USA.

Maxwell, B. D., E. Lehnhoff and L. J. Rew. 2009. The rationale for monitoring invasive plant populations as a crucial step for management. Invasive Plant Science and Management 2:1-9.

Mayor, S. J., D. C. Schneider, J. A. Schaefer, and S. P. Mahoney. 2009. Habitat selection at multiple scales. Ecoscience 16:238-247.

Mazzotti, F. J., M. McEachern, M. Rochford, R. N. Reed, J. K. Eckles, J. Vinci, J. Edwards, and J. Wasilewski. 2014. *Tupinambis merianae* as nest predators of crocodilians and turtles in Florida, USA. Biological Invasions 17:45-50.

McEachern, M. A., A. A. Y. Adams, P. E. Klug, L. A. Fitzgerald, and R. N. Reed. 2015. Brumation of introduced black and white tegus, *Tupinambis merianae* (Squamata: Teiidae), in Southern Florida. Southeastern Naturalist 14:319-328.

Mehta, S. V., R. G. Haight, F. R. Homans, S. Polansky, and R. C. Venette. 2006. Optimal detection and control strategies for invasive species management. Ecological Economics 61:237-245.

Mercolli , C. and A. Yanosky. 1994. The diet of adult Tupinambis-teguixin (sauria, teiidae) in the eastern chaco of Argentina. *The Herpetological Journal* 4(1):15-19.

Milstead, W. W. 1961. Notes on Teiid lizards in southern Brazil. Copeia 4:493-495.

Myers, R.L. 1990. Scrub and high pine. Pages 150-193 *in* R.L Myers and J.J. Ewel, eds. Ecosystems of Florida. University of Central Florida Press; Orlando, Florida.

Naretto, S., G. Cardozo, C. S. Blengini and M. Chiaraviglio. 2015. Importance of reproductive biology of a harvested lizard, *Tupinambis merianae,* for the management of commercial harvesting. Wildlife Research 42:697-704.

Pernas, T., D. J. Giardina, A. McKinley, A. Parns, and F. J. Mazzotti. 2012. First observations of nesting by the Argentine black and white tegu, *Tupinambis merianae,* in South Florida. Southeastern Naturalist 11:765-770.

Pianka, E. R. 1974. Niche overlap and diffuse competition. Proceedings of the Natural Academy of Science of the United States of America 71:2141-2145.

Pike, D. A. and J. C. Mitchell. 2013. Burrow-dwelling ecosystem engineers provide thermal refugia throughout the landscape. Animal Conservation 16:694-703.

Pimentel, D., R. Zuniga, and D. Morrison. 2005. Update on the environmental and economic costs associated with invasive species in the United States. Ecological Economics 52:273-288.

Platenberg, R. J. 2007. Impacts of introduced species on an island ecosystem: non-native reptiles and amphibians in the US Virgin Islands. In: Witmer, G.W., Pitt, W.C., Fagerstone, K.A. (Eds.), Managing Vertebrate Invasive Species: Proceedings of an International Symposium. National Wildlife Research Center, Fort Collins, pp. 168–174.

Presch, W. 1973. A review of the tegus, lizard genus *Tupinambis* (Sauria: Teiidae) from South America. Copeia 1973:740-746.

Ratcliffe, N., M. Bell, T. Pelembe, D. Boyle, R. B. R. White, B, Godley, J. Stevenson, and S. Sanders. 2009. The eradication of feral cats from Ascension Island and its subsequent recolonization by seabirds. Oryx, 44:20–2.

Ricketts, T. H. 2001. The matrix matters: effective isolation in fragmented landscapes. American Society of Naturalists 158:87-99.

Row, J. R. and G. Blouin-Demers, 2006. Kernels are not accurate estimators of home-range size for herpetofauna. Vopeia 2006:797-802.

Sanders, C. E., G. J. Tattersall, M. Reichert, D. V. Andrade, A. S. Abe, and W. K. Milsom. 2015. Daily and annual cycles in thermoregulatory behavior and cardio-respiratory physiology of black and white tegu lizards. Journal of Comparative Physical Biology 185:905-915.

Scott, C. 2004. Pages 41-15 *in* Endangered and Threatened Animals of Florida and Their Habitats. University of Texas, Austin, TX.

Silva, J. S., A. C. A. El-Deir, G. J. B. Moura, and R. R. N. Alves. 2014. Traditional ecological knowledge about dietary and reproductive characteristics of *Tupinambis merianae* and *Hoplias malabaricus* in semiarid northeastern Brazil. Human Ecology 42:901-911.

Simberloff, D. and B. Von Holle. 1999. Positive interactions of nonindigenous species: invasional meltdown? Biological Invasions 1:21–32.

Simberloff, D., 2013. Invasive Species: What everyone need to know. Oxford University Press, New York, NY.

Sovie, A. R., R. A. McCleery, R. J. Fletcher, and K. M. Hart. 2016. Invasive pythons, not anthropogenic stressors, explain the distribution of a keystone species. Biological Invasions 18:3309-3318.

Strayer, D.L., V. T. Eviner, J. M. Jeschke, and M. L. Pace. 2006. Understanding the long-term effects of species invasions. TRENDS in Ecology and Evolution 21:645-651.

U. S. Fish and Wildlife Service (USFWS). 1999. The Ecological Communities: Florida Scrub. Pages 3.31-3.68 *in* Multi Species Recovery Plan for South Florida. Atlanta, GA.

van Leeuwen, J. P., A. Catenazzi, and M. Holmgren. 2011. Spatial, ontogenetic, and sexual effects on the diet of a Teiid lizard in arid South America. Journal of Herpetology 45:472-477.

Vitousek, P. M., H. A. Mooney, J. Lubchenco, J. M. Melillo. 1997. Human Domination of Earth’s Ecosystems. Science 277:494-499.

White, G., and R. Garrott. 1990. Analysis of wildlife radio-tracking data. Academic Press, San Diego, California.

Whittaker, R. J., and J. M. Fernández-Palacios. 2007. *Island biogeography: Ecology, evolution, and conservation,* 2nd ed. Oxford: Oxford University Press, New York, NY.

Wiles, G. J., J. Bart, R. E. Beck, and C. F. Aguon. 2003. Impacts of the brown tree snake: patterns of decline and species persistence in Guam’s avifauna. Conservation Biology 17:1350–1360.

Wood, J. P., T. S. Campbell, and R. B. Page. 2015. Characterization of 14 novel microsatellite loci in the Argentine black and white tegu *(Salvator meianae)* via 454 pyrosequencing. Amphibia-Reptilia 36:444-449.

BIOGRAPHICAL SKETCH

Marie-Therese Offner, known as Tessie by her colleagues and friends, has had a passion for wildlife since early childhood. This passion was cultivated by her loving family who supplied many outlets for her curiosity of the natural world. She has fond memories of the Missouri countryside where she enjoyed endless opportunities for outdoor play.

Tessie graduated in 2012 with her bachelor’s degree in biology from the University of Tampa. She has over a decade of experience working in a career with wildlife, including roles as an environmental educator with The Florida Aquarium and as a nonnative species biologist with the Florida Fish and Wildlife Conservation Commission (FWC). She began working with Argentine black and white tegus in the summer of 2012 with Dr. Todd Campbell at the University of Tampa, and later transitioned to her role at FWC before she began her master’s degree at the University of Florida with her advisor Dr. Steve Johnson. She graduated from the University of Florida in December 2017 with her master’s degree in wildlife ecology and conservation.