

Niche partitioning strategies of two endemic *Sphaerodactylus* (Squamata: Gekkota) species found at the Salt Flats Refuge in Cabo Rojo, Puerto Rico

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Abstract

The conservation of endemic reptiles is essential to maintain balance in fragile island ecosystems. My research aimed to provide novel information regarding the ecology of the geckos *Sphaerodactylus nicholsi* and *S. roosevelti* while in sympatry at The Salt Flats Refuge in Cabo Rojo, Puerto Rico. Using transects during one calendar year I captured and marked individuals of each species and collected microhabitat data such as substrate type, over-story cover percent and time of activity. In addition, I obtained morphometrical data such as snout-vent length (mm), tail length and weight (g) of each individual. Furthermore, I recorded age category, sexed adult individuals whenever possible, and noted any egg-bearing females. My results demonstrate interspecific and intraspecific spatial and temporal resource partitioning at The Salt Flats Refuge. My findings are relevant to future preservation efforts concerning endemic and worldwide sphaerodactylids threatened by unprecedented climate change effects.

Resumen

La conservación de reptiles endémicos es esencial para mantener el balance dentro del ecosistema frágil de islas. El objetivo de mi investigación fue proveer información novedosa sobre la ecología de los geos *Sphaerodactylus nicholsi* y *S. roosevelti* en simpatría dentro del Refugio Las Salinas en Cabo Rojo, Puerto Rico. Se realizaron transectos durante un año para capturar y marcar individuos de ambas especies con el fin de obtener datos de microhábitat tales como: tipo de sustrato, cobertura vegetal (%), y hora de actividad. En adición, obtuve datos morfométricos tales como longitud de hocico a cloaca y largo del rabo (mm), en adición a peso (g). Además, anote categoría de edad, sexo del individuo donde fuese posible, y presencia de hembras con huevos. Mis resultados demuestran partición de recursos temporales y de hábitat de maneras inter- e intra-específicas dentro del Refugio Las Salinas. Mis hallazgos son relevantes a futuros esfuerzos de conservación de sphaerodactílicos, endémicos y mundiales, amenazados por cambios climáticos sin precedentes.

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Dedication

I dedicate this manuscript to the two main pillars in my life.

My mother, Irma Lois Dorr, taught me the importance of hard work and the value of a great education. She always encouraged me to be whatever I wanted to be. I am eternally grateful for her love, sacrifice and strength.

Without the unbridled support of my husband, Carlin Ortiz, I never would have made it through this degree. I am sincerely grateful to him for accompanying me on this journey as my trusty field assistant and my rock when I needed to be steadied. Most importantly, I thank him for his constant, unflinching belief in me.

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Introduction

Niche Partitioning:

The habitat of an organism can be described as the physical space where it normally lives. This broad definition also includes biotic and abiotic factors that allow an organism or community to flourish in this given geographical space. For example, a habitat should be able to provide adequate temperatures, humidity levels, nutrients, shelter as well as potential mates. By contrast, a microhabitat can be differentiated in terms of a smaller spatial scale and more specialized use of resources within a given habitat. Usually, microhabitats possess a varied array of unique parameters different from the rest of habitat but crucial for the existence of specific organisms.

The ecological niche of a species can be described as a compendium of interactions between biotic and abiotic factors that ultimately ensure the fitness of a species within a given geographical range (Hirzel and Le Lay 2008). While a Grinnelian niche focuses on a species' distribution, habitat and behavior within a niche, an Eltonian niche constitutes the species' relation to trophic interactions and other species (For example, predation and competition) (Alley 1982 and Hirzel and Le Lay 2008). A Hutchinson niche is defined as a "hypervolume" influenced by environmental parameters which can support species "indefinitely" (Pironon et al. 2017).

Resource partitioning can be defined as the division of resources found in a given habitat used by differing species with overlapping distribution (Tillman 1987). These divisions are guided by differences in resource usage between species. The major purpose of resource partitioning is to analyze the limits of interspecific competition on the number of species that can stably coexist (Schoener 1974). It has been demonstrated that species cannot coexist for long periods of time if they use the same types of resources (Gause 1934; Schoener 1974). For example, during instances of competitive exclusion, the dominant species will force the weaker species to restrict or partition habitat or resource use in order to avoid direct competition. Due to this shift towards ecological niche differences, species in competition will eventually display varying niche characteristics in places where they co-exist. There can be many types of resource partitioning, some of these include: habitat, food and temporal partitioning. However, Toft (1985) stated that

the three main causes of partitioning are competition, predation and physiological constraints. In addition, there exists three types of competition: (1) Interference, which is usually associated to direct confrontation over resources, (2) Exploitative in which one species denies resources to another, and (3) Diffuse competition, which is similar to exploitative but instead involves various species denying resources to another (Heatwole and Taylor 1987). The causes of partitioning rarely act independently but “overlap forming complex webbed mechanisms within communities” (Toft 1985). In other words, all factors involved in resource utilization (Food, Habitat and Time) are related to each other, and will have a positive or negative effect on species survival and rarely stand alone.

Petren and Case (1998) concluded that by manipulating the food supply and topography of a shared habitat between invasive *Hemidactylus frenatus* and the native *Lepidodactylus lugubris* they could ultimately reduce interspecific competition by means of reducing foraging efficiency of each species in different manners. On the other hand, Roughgarden (1976) proposed that communities utilize mechanisms such as extinction and invasion to help species thrive throughout limiting similarities. For example, Roughgarden describes Resource Partitioning as being an “evolutionary compromise” between individual and ultimately species extinction and the obstacles of resource type shifting.

Jaeger (1970) showed that two species of closely related *Plethodon* salamanders, *P. cinereus* and *P. shenandoah*, compete strongly under natural conditions and exhibit sharp microhabitat partitioning that results from interspecific competition influenced by physiological tolerances of individual species. He demonstrated that *P. cinereus* was the superior competitor. However, *P. shenandoah* can tolerate dryer conditions than *P. cinereus* and has a physiological advantage in dryer microhabitats.

In addition, to explain the separation between ancestrally nocturnal geckos and derived diurnal species, Gamble et al. (2015) stated that niche partitioning by means of *temporal division* may have caused morphological, physiological, behavior and ecological modifications between species. Hut et al. (2012) defined the daily temporal niche of a species as the time of day (diurnal, nocturnal or crepuscular) at which said species demonstrates increased locomotor activity. These temporal adaptations would

benefit geckos that inhabit areas with increased predation risk and competition while taking advantage of available resources not in use (Gamble et al. 2015). Geckos originally transitioned to nocturnal niche usage to exclude competition with diurnal lizards and to take advantage of nocturnal resources that were not being used, thus avoiding extinction (Vitt et al. 2003; Gamble et al. 2015).

Nava (2004) studied microhabitat selection, resource partitioning, and EWL rates of 3 species of *Sphaerodactylus* (*S. gaigae*, *S. macrolepis* and *S. townsendi*) on the eastern region on Puerto Rico. He reported data of each species in allopatry as well as sympatry and concluded greater variations in microhabitat use when species are in sympatry. In the presence of interspecific competitors, *Sphaerodactylus* partition microhabitats based on physiological capabilities (Nava op. cit.).

Similarly, Harmon et al. (2007) confirmed that diurnal arboreal *Phelsuma* geckos in Mauritius (Indian Ocean) display habitat partitioning. These geckos shift habitat use in sympatry, thus suggesting marked levels of interspecific competition between this genus.

The development of novel coping strategies such as resource partitioning among similar yet different competing species helps ensure that both thrive throughout hardships (Roughgarden 1976). It has not yet been fully elucidated the correct mechanisms associated with resource division of interspecific terrestrial geckos at The Salt Flats, Cabo Rojo. However, Gamble et al. (2015) stated that studying partitioning in geckos is important because temporal niche shifts are rare among other animals and can be used for broader studies on evolution and ecology (Schoener 1974).

***Sphaerodactylus* biology**

Sphaerodactylids are miniscule terrestrial geckos considered the smallest vertebrate amniotes on the planet (Hedges and Thomas 2001; López-Ortiz and Lewis 2002). The genus currently encompasses a neotropical distribution, including most of the Caribbean, Central and South America, as well as small areas of the North American continent (Vitt et al. 2014; Powell and Henderson 1999). The two smallest species are *S. ariasae* in Dominican Republic, with a snout vent length of 16 mm, followed by *S. parthenopion*, found on the Virgin Islands, which measures 18mm.

Sphaerodactylids display qualities that are in direct contrast to their nocturnal ancestry and thus the majority of existing geckos (Gamble et al. 2015). For instance, they are considered diurnal or crepuscular being most active during daylight hours. This trait is considered a relatively recent evolutionary adaptation with the aim of possibly decreasing predation, competition, and/or safeguarding against unfavorable climate conditions (Gamble et al. 2015). Furthermore, in relation to their diurnal activity patterns, sphaerodactylids also contain adaptations to their eyes; the first and most obvious being a round pupil within a smaller eye when compared to nocturnal families (Gamble et al. 2015), and others like the possession of unique internal structures that function to filter and regulate light (Gamble et al. op. cit). Examples of these specialized eye structures are cone-like photoreceptor cells that contain oil drops in the retina, as well as UV filtering proteins within the crystalline lens both absent in nocturnal geckos (Gamble et al. op. cit.). However, it should be noted that sphaerodactylids lack eyelids, a common trait present among geckos.

In addition to visual adaptations, sphaerodactylids also differ from other Gekkota families in their voiceless nature. Instead, it has been suggested that members of *Sphaerodactylus* rely on visual as well as chemical signals for communication (Regalado 2003). Another characteristic of this group is the spherical projection on the tip of each digit, feature that is used to name the genus “*Sphaerodactylus*” which means “balloon-round like” finger.

As a consequence of their tiny size and ectothermic nature, *Sphaerodactylus* geckos are very susceptible to desiccation and, thus, normally remain hidden under leaf litter and/ or underground, emerging from these areas at specific hours where the heat and

sunlight are not a direct threat to their survival. Unfortunately, *Sphaerodactylus* species lack physiological adaptations to cope with extreme thermal pressures such as low humidity and high temperature and, therefore, are forced to rely on behavioral thermoregulation to regulate their metabolism (Allen and Powell 2014). Similarly, Leclaire (1978), Snyder (1979), Nava (2001) and Steinberg et al. (2007) all noted that the members within the genus *Sphaerodactylus* are vastly influenced by their microhabitat selection to avoid desiccation.

Puerto Rico is host to at least nine species of *Sphaerodactylus* that inhabit a wide range throughout the varied elevations and microclimates found on the island (Schwartz and Henderson 1991; Rivero 2006). Three species are distributed between Mona, Monito and Desecheo islands and six species are found on the mainland (Rivero 1998, 2006). Other species are yet to be described, like a new species found in Rincón (Díaz-Lameiro et al. 2013) and another from Culebra Island (Rios Franceschi et. al 2016). One species, *S. macrolepis*, is represented by nine subspecies (Rivero 1998); however, unpublished studies suggest that *S. macrolepis* in Puerto Rico should be considered a different species.

The Salt Flats refuge in Cabo Rojo, located near the southwestern area of Puerto Rico, is home to two xeric species: *S. nicholsi* and *S. roosevelti*, which differ greatly in size. *Sphaerodactylus nicholsi* is the smallest gecko in Puerto Rico with an approximate size of 20 mm SVL (Snout-Vent-Length); whereas, in contrast, *S. roosevelti* is the largest within the genus with an approximate size of 39 mm SVL (Rivero 2006). Aside from the difference in size, these two species also differ in that *S. roosevelti* displays sexual dimorphism. Unlike the males, females of *S. roosevelti* females display marked black longitudinal lines that run along the length of the body and face which contrast with the rest of their white-grey colored scales (Rivero op. cit.) (Figure A). At first glance it would seem that the males' body is the same color throughout but some exhibit grey-light blue longitudinal lines on dorsal side of body (Rivero op. cit.) (Figure B). Physical attributes for *S. nicholsi* include a range of dark brown-black colored scales with darker flecks throughout, and distinctive marks such as a “U” or “V” chevron pattern at the base of tail and crescent moon shape on dorsal head region (Rivero op. cit.) (Figure C). Similarly, both species have a tendency to display the black scapular patch with white ocelli characteristic of the genus, although uncommon in *S. roosevelti* males (Rivero op. cit.).



Figure A: *Sphaerodactylus roosevelti* (female)



Figure B: *Sphaerodactylus roosevelti* (male)



Figure C: *Sphaerodactylus nicholsi*

Due to the elusive behavior and small habitat range on the island (southern Puerto Rico) of *S. roosevelti*, little is known about the ecology and general biology of this endemic species. Furthermore, any information on interspecific data is evidently lacking in literature. The available scientific information has been limited to skin mechanics and morphology (Bauer et al. 1992), skull anatomy (Daza et al. 2008), presence and role upon the lizard community of Guánica dry forest (Genet et al. 2001), and, a brief description of phenotype focusing on male and female differences. In addition, information on distribution and activity wherein it is suggested that this species may possibly be considered more nocturnal than other sphaerodactylids in Puerto Rico (Rivero 1998, 2006; Schwartz and Henderson 1991).

In contrast to the relative absence of information available on *S. roosevelti*, *S. nicholsi* has been studied in more detail. Although, similar to *S. roosevelti*, vital information about interspecific ecology, such as microhabitat selection, and temporal activity patterns are yet to be determined. Some of the most prominent studies on the species were performed by López-Ortiz and Lewis (2002, 2004), in which they described increased summer season reproductive trends in gravid females, habitat selection parameters and suggested metapopulation as the cause of the abundant distribution of

species throughout Fish and Wildlife refuge in Cabo Rojo. Genet et al. (2001) described *S. nicholsi* as one of the most abundant lizards present in the Guánica dry forest and described microhabitat selection parameters within forest limits. Based on phylogeny and data on genetic isolation, Murphy et al. (1984) suggested that, *S. nicholsi* and *S. townsendi* should be considered separate species. However, Díaz-Lameiro et al. (2013) states that they did not find genetic evidence of speciation between them. Interestingly, both are currently considered the two most closely related (genetically) sphaerodactylids in Puerto Rico. In addition, molecular data suggest that *S. nicholsi* and *S. roosevelti* belong to two separate clades within sphaerodactylids that most likely originated from Hispaniola (Díaz-Lameiro et al. op.cit.).

As a consequence of their tiny size and ectothermic nature, *Sphaerodactylus* geckos are very susceptible to desiccation and, thus, normally remain hidden under leaf litter and/ or underground, emerging from these areas at specific hours where the heat and sunlight are not a direct threat to their survival. Unfortunately, *Sphaerodactylus* species lack physiological adaptations to cope with extreme thermal pressures such as low humidity and high temperature and as such are forced to rely on behavioral thermoregulation to regulate their metabolism (Allen and Powell 2014). Similarly, Leclaire (1978), Snyder (1979), Nava et al (2001), and Steinberg et al. (2007) all noted that the members within the genus *Sphaerodactylus* are vastly influenced by their microhabitat selection to avoid desiccation.

Climate Warming and Habitat Disruption:

Huey et al. (2009) emphasized that increasing temperatures will bring an array of conflicts to lizards, such as possible increased competition and predation from open habitat species such as those included in the genus *Pholidoscelis* (*Ameiva*), which have previously been reported as a primary predator of *Sphaerodactylus* (López-Ortiz and Lewis 2004). If this were the case, it would also possibly cause a change in the structure of lizard communities and in the food web of tropical lizards (Huey et al. op.cit.). Another alarming effect is the fact that over-heated lizards, during summer time, may experience potential decreased levels of reproduction and growth rates (Huey et al. op.cit.). Some species of lizards in the genera *Anolis* and *Sphaerodactylus* were already found inhabiting areas of Puerto Rico in the summer that were thermally unsuitable (Álvarez, 1992). He noted that, similar to *Anolis*, *Sphaerodactylus* species are considered heat intolerant with a maximum critical temperature (CT max) below 40° C and a thermal preference (Tp) of below 30° C (Álvarez 1992). Allen and Powell (2014) reported that environmental temperatures were higher than preferred by *S. macrolepis* in Puerto Rico, suggesting that nocturnal observations of the species were influenced by increased humidity and optimal temperature gradients.

Moreover, when compared to temperate species, tropical species are at an increased risk during climate warming, especially those that inhabit arid environments (Gunderson and Leal 2012). When studying tropical *Anolis cristatellus* in mesic and xeric habitats, Gunderson and Leal (2012) concluded that xeric populations of *A. cristatellus* are more vulnerable to increase in temperatures than mesic congeners. They argued that the reason for this is due to the fact that xeric populations currently already occupy habitats with high temperatures close to thermal limits. In xeric environments, *A. cristatellus* performs behavioral thermoregulation by selecting perches within cooler patches of arid microhabitat (Gunderson and Leal op. cit.). If climate warming increases by just 3 degrees Celsius over the next 100 years, the species will not have a way to mitigate overheating, and as a consequence will experience a decrease in physiological performance of 30% (Gunderson and Leal op. cit.). In contrast, mesic populations of the species will have an increase in physiological capacity of 4% and, thus, will not be

drastically affected by this increase in temperature because their thermal gradients would still be found within comfortable limits for survival (Gunderson and Leal op. cit.).

Aside from the obvious threats caused by climate change, habitat disruption by anthropogenic sources also poses a direct significant risk to small leaf litter gecko populations. Vitt et al. (2005) studied three different genera (*Coleodactylus*, *Pseudogonatodes* and *Lepidoblepharis*) of closely related tropical geckos in Brazil and Nicaragua and noted that their diminutive size and microhabitat selection (leaf litter patches) exposed them to high risks of extirpation due to alterations in their preferred habitat. Without trees, there can be no leaf litter patches and thus no geckos to inhabit these habitats. Vitt et al. (2005) stated that by opening up canopy habitats there will be an increase in predation by larger, more active lizards that feed on smaller vertebrates. In addition, Nava (2004) studied three species of *Sphaerodactylus* in Puerto Rico and suggested that this genus is vulnerable to anthropogenic disturbances due to the restricted specialized habitats and dispersal abilities of the species.

Objectives and hypotheses

The following objectives and hypotheses were addressed:

(1.) To identify and describe microhabitat selection of *Sphaerodactylus nicholsi* and *Sphaerodactylus roosevelti*

To describe and document differences between interspecific and conspecific microhabitat use between *Sphaerodactylus nicholsi* and *Sphaerodactylus roosevelti* in addition to age category comparisons of each species.

Hypothesis 1: Differences in size *leads to differences in microhabitat use*. If study species vary in size, then these differences will have a considerable effect on each species niche requirements. This may include differences in the *microhabitat* each species will utilize.

Hypothesis 2: I expect that differences in sexes as well as age and development levels will influence niche requirements, thus propagating disparity in microhabitat use. I will identify microhabitat preference between male and female of *S. roosevelti* in addition to conspecific age category microhabitat use of *S. nicholsi* and *S. roosevelti*. Furthermore, each species niche requirements should also vary in overall species' temporal activity preference.

(2.) To identify and describe temporal activity preference of *S. nicholsi* and *S. roosevelti*

To prove interspecific and conspecific differences in species' temporal activity preference.

Hypothesis 1: I postulate that due to the differences in size both species will also differ in their preferred foraging activity patterns. Preferred nocturnal temporal patterns will be greater for *S. roosevelti* than in crepuscular *S. nicholsi*; thus, influencing resource and or niche partitioning parameters.

Hypothesis 2: Variations in temporal activity patterns may possibly exist between sexes of the species *Sphaerodactylus roosevelti*, as well as between the age categories of each species.

(3.) To identify resource and/or niche partitioning parameters between *S. nicholsi* and *S. roosevelti* at The Salt Flats Refuge in Cabo Rojo.

Hypothesis: I postulate that differences in microhabitat selection and temporal activity patterns exist between *S. nicholsi* and *S. roosevelti*, thus influencing resource and/or niche partitioning between these two species at The Salt Flats refuge in Cabo Rojo, Puerto Rico.

Methods

Study Site



Study Site Description

Ecological Parameters: Transect surveys were performed during early morning between the hours of 6:00-10:30 a.m., and late afternoon to early evening from 4:00 to 9:30 p.m. Four study sites located along trails at the Salt Flats Refuge in Cabo Rojo were chosen based on presence of leaf litter patches and shady canopy cover (Genet et al. 2001; Vitt et al. 2005). Each site was divided into 2 m x 2 m quadrants (Bentz et al. 2011; Allen and Powell 2014). During every visit, the order in which the sites were surveyed was chosen randomly with a digital number generator (1-4), and the leaf litter quadrant inside each site was chosen the same way. This ensured unbiased sampling.

Upon capturing an individual, it was identified to species and classified by age as one of the following: hatchling, juvenile, or adult, based on physical attributes such as color, size and robustness. I used the following Snout Vent Length ranges for age category classifications of *S. roosevelti*; Hatchlings: 18-22mm, Juveniles: 23-27mm and Adults: 28mm-32mm. For *S. nicholsi* hatchling identification, I used parameters previously established by López-Ortiz and Lewis (2002). The following Snout Vent Length ranges were used for age category classifications of *S. nicholsi*; Hatchlings: 8-12mm, Juveniles: 13-17mm and Adults: 18-22mm. Furthermore, I sexed individuals whenever possible. Females that displayed evident egg bearing were categorized as gravid. In addition, morphometrics were gathered based on snout vent length (SVL) and tail length (TL) in mm, which were obtained using an electronic digital caliper. The animal's weight in grams (g) was also measured using a Pesola[®] scale with a maximum of 10g. Once all morphometric measurements were taken, all specimens were marked using a specific paint mark sequence to avoid analyzing same specimen within the same month (López-Ortiz and Lewis 2002). Marking specimen allowed also for keeping a record of all recaptured individuals and, thus, elucidating vital home range data. Once marked, all individuals were returned to their original capture site. During habitat and/or microhabitat descriptions, substrate type was noted as one of the following: Leaf litter (LL), Mixed (M), Sand (BG), Vegetation (V) or Other (O). Additionally, leaf litter substrate depth was measured in centimeters. Also, percent (%) of overstory cover of vegetation was measured using a Model-C Spherical Densiometer in which two-four readings were performed using cardinal directions facing North, South, East and West;

then averaged. Furthermore, the most prevalent vegetation present in each site was identified with the assistance of Mrs. Jeanine Vélez Gavilán from UPRM Herbarium to assert accurate microhabitat selection vegetation parameters. In order to discover correlations and differences between interspecies microhabitat selection and environmental parameters, HOBO[®] data logger devices were used to record air and topsoil temperature (Proseries Temp/RH Model H-08-032-08) (Vitt et al. 2005; Steinberg et al. 2007; Bentz et al. 2011).

Statistical Analyses

Infostat[®] software was used to perform statistical analyses

In order to test “goodness of fit” between species, categorical data such as substrate type and temporal category were analyzed using Contingency tables and Chi-Square (Pearson). The Wilcoxon test for independent samples was used to test significant differences between species use of leaf litter depth (in cm) as well as overstory cover (%). Additionally, the linear body condition index of each species was tested using regressions. In order to test significant differences in temperature preference between species, T- test for independent samples was used. Furthermore, Multivariate Analysis was used to summarize main ideas that support hypotheses. Categorical data such as temporal category and substrate type use between species were summarized using a Multiple Correspondence Analysis (MCA). In addition, Principal Component Analysis (PCA) was used to demonstrate the relationship between numerical data such as SVL, TL, overstory cover (%) and Leaf Litter Depth of each species.

Intraspecific age category preferences were analyzed using Contingency tables and Chi-Square (Pearson) for substrate type, temporal use, and seasonal prevalence. Numerical data, such as overstory cover (%), leaf litter depth (cm) and morphometrics (SVL, TL, Weight), were tested using non-parametric ANOVA- Kruskal Wallis with pairwise comparisons. Male and female *Sphaerodactylus roosevelti* comparisons for overstory cover (%) and Leaf Litter depth (cm) were analyzed using T- test for independent samples. In addition, morphometrics (SVL, TL, Weight) were analyzed for significant differences using non- parametric ANOVA- Kruskal Wallis. Furthermore,

Contingency tables and Chi- square (Pearson) were used to analyze “goodness of fit” for categorical data such as substrate type and temporal patterns.

The influence of lunar phases on *S. roosevelti* was tested using Contingency tables and Chi- Square. Reproductive parameters of *S. nicholsi* and *S. roosevelti* were compared by seasons of the year using Contingency tables and Chi- Square (Pearson).

Results

Interspecific Resource Partitioning Between *S. nicholsi* and *S. roosevelti*

A total of 667 individuals of *S. nicholsi* and 124 individuals of *S. roosevelti* were captured during the study period. I can state that the type of substrate predominantly selected will indeed vary by species (Chi-Square, df 4; p-value <0.0001).

Sphaerodactylus nicholsi predominantly selected leaf litter (LL) as substrate type with an absolute frequency of 381/667 individuals and a relative frequency by rows of 0.57/1.00 (See Table 1, p.81); whereas *S. roosevelti* selected vegetation (V) as primary substrate type with an absolute frequency of 66/124 individuals and a relative frequency by rows of 0.53/1.00.

For the second most common substrate type used I saw differences in substrate selection between species again. *Sphaerodactylus nicholsi* had an absolute frequency of 105/667 individuals for vegetation (V) as second most commonly used substrate type, with a relative frequency by rows of 0.16/1.00. In contrast, *S. roosevelti* preferred bare ground (BG) with an absolute frequency of 36/124 individuals and a relative frequency of rows of 0.29/1.00. These points are illustrated more clearly in Figure 1, where I can see how the cumulative proportions of substrate type use between species differs, thus supporting my results.

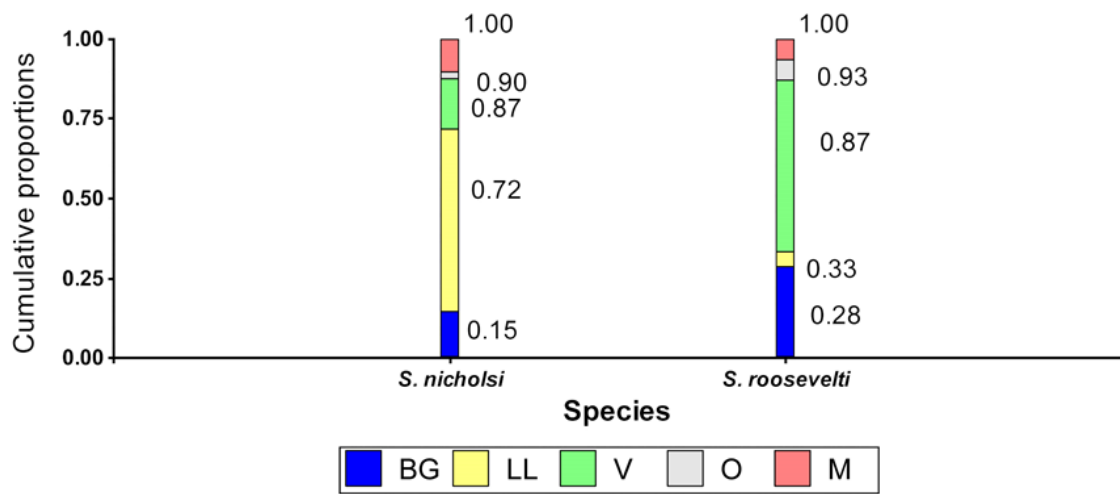


Figure 1. Comparison of substrate type selection between *Sphaerodactylus nicholsi* and *S. roosevelti*

BG-Bare ground, LL- leaf litter, V-Vegetation, O-Other and M-Mixed

Significant differences exist between substrate type selected by species

(Chi-Square, p-value < 0.0001). *Sphaerodactylus nicholsi* predominantly selects leaf litter, whereas *S. roosevelti* tends to select vegetation .

In Table 2 (p.82), I compare the use of substrate type “other” between species. The categories for “other” are as follows: Termite Mound (TM), Tree Trunk (TT), Debris (D), and Rock (R). No differences were found between species using the same “other” substrate (Chi-Square, df 3; p-value 0.2280). In this case “other” substrate was termite mounds (TM). As illustrated in Figure 2, *S. roosevelti* was only found using termite mounds in the “other” substrate category. In Table 2, all eight individuals of *S. roosevelti* were found in this category versus nine individuals out of fifteen for *S. nicholsi*. The remaining six individuals of *S. nicholsi* were divided up evenly between Debris (D), Tree Trunk (TT) and Rock (R).

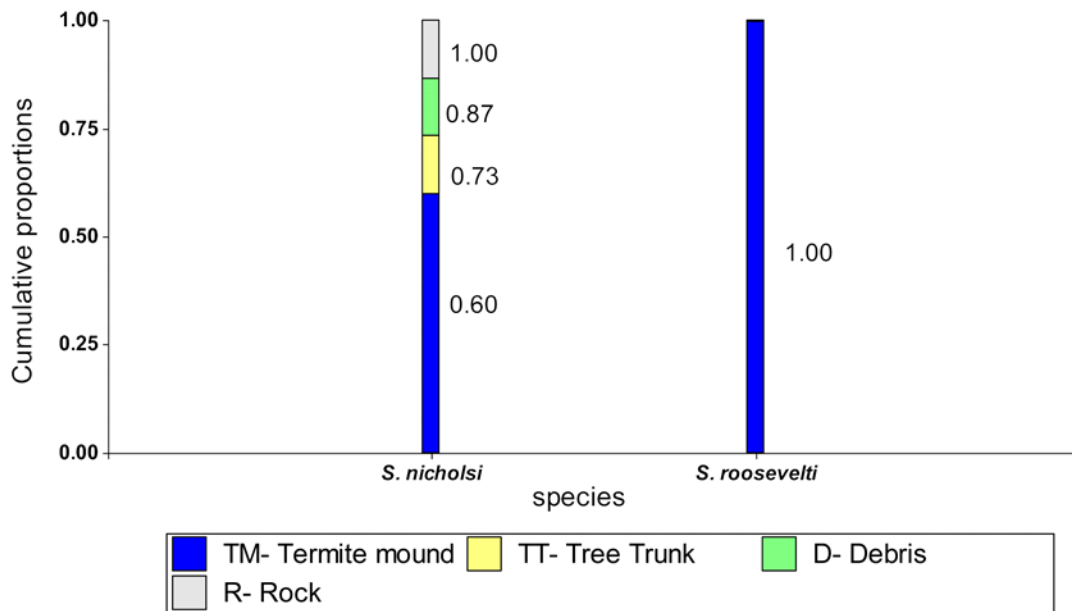


Figure 2. Comparison between *Sphaerodactylus nicholsi* and *S. roosevelti* of “Other” type of substrate selected .

No significant differences exist between species within the “Other” substrate type selected (Chi-Square,p-value 0.2280). Both species were predominantly found in termite mounds.

Significant differences exist in the vegetation substrate species preferred by *S. roosevelti*. (Table 3, p.83, Chi Square, df 2; p-value <0.0001). I can clearly see that the majority (68%) of individuals of *S. roosevelti* were found on *Fimbristylis cymosa* (Figure 3). The second most abundant plant used by *S. roosevelti* was *Batis maritima* (27%) and, lastly, with only 5%, *Sesuvium* sp. Furthermore, Table 4 (p.84), lists all the plants that were found within the study site perimeters. Aside from the vegetation used by *S. roosevelti*, the black and white mangroves, as well as the trees listed, were responsible for the leaf litter that *S. nicholsi* predominantly selects as substrate.

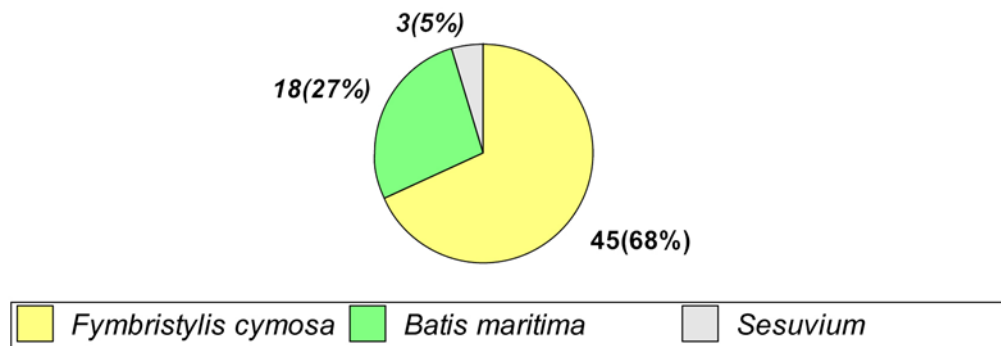


Figure 3. Vegetation used by *Sphaerodactylus roosevelti*
Sphaerodactylus roosevelti predominantly selected *Fymbristylis cymosa* (Chi-Square, p-value <0.0001).

In Table 5 (p.85), I compared leaf litter depth (cm) used by species. No differences were detected in leaf litter depth selected between *S. nicholsi* and *S. roosevelti* (Wilcoxon Test- Mann- Whitney U, p-value 0.1677) . Although Figure 4 demonstrates that *S. nicholsi* used areas with more leaf litter depth (mean=2.69 cm and SD \pm 1.38) than *S. roosevelti* (mean=2.07 cm and SD \pm 1.30), they are not different enough to be considered statistically significant.

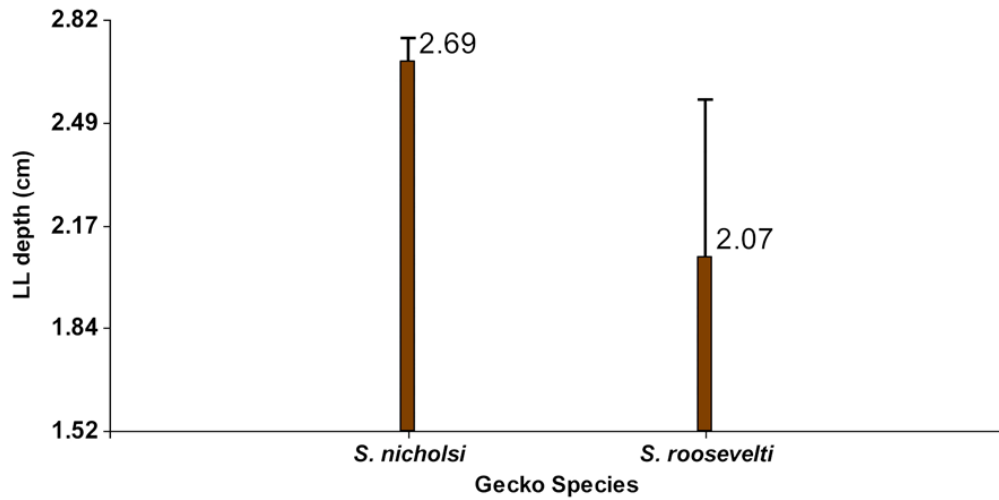


Figure 4. Comparison of leaf litter depth (cm) selection between *Sphaerodactylus nicholsi* and *S. roosevelti*

No significant differences exist in leaf litter selection between species (Wilcoxon Test-Mann- Whitney U, p-value 0.1677).

In terms of the overstory cover percentage, *S. nicholsi* clearly selects a higher percentage of overstory cover than *S. roosevelti* (Wilcoxon Test-Mann-Whitney U, p-value <0.0001) (Table 6, p.86). Figure 5 shows the marked variation between the means of each species, *S. nicholsi* . with a mean of 71.39% \pm 36.79), whereas *S. roosevelti* has a mean of 23.10% \pm 35.97).

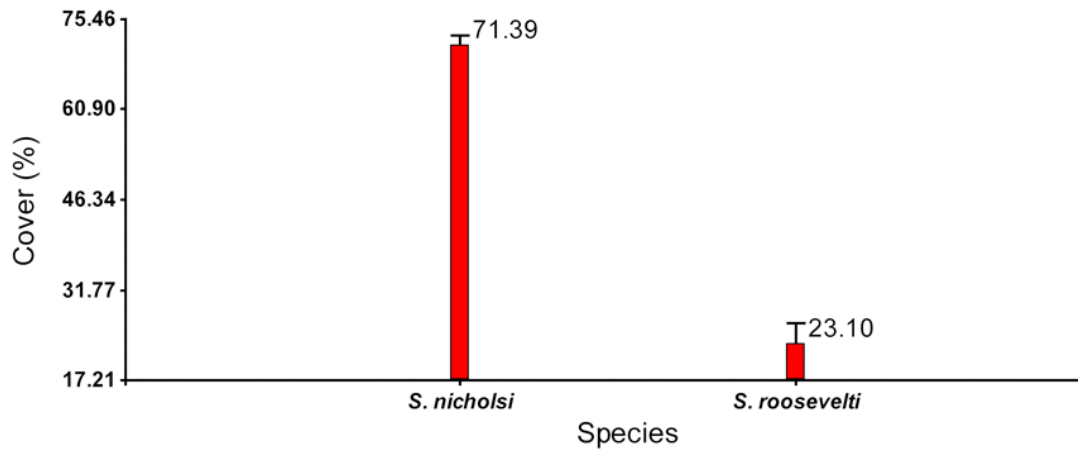


Figure 5. Comparison Over story cover selection between *Sphaerodactylus nicholsi* and *S. roosevelti*

Significant differences exist in the over story cover selection between species (Wilcoxon Test-Mann-Whitney U, p-value < 0.0001). *Sphaerodactylus nicholsi* predominantly selects shadier areas with higher over story cover mean than *S. roosevelti*.

Temporal use preference between *S. nicholsi* and *S. roosevelti* was evaluated (Table 7,p.87). Temporal categories were as follows: AM (6:00 a.m.-12:00 p.m.), PM (12:01-6:44 p.m.) and night (6:45 p.m.-12 a.m.). *Sphaerodactylus nicholsi* and *S. roosevelti* vary in their temporal use preference (Chi -Square, df 2; p-value <0.0001) . Upon review of table 7, *S. nicholsi* predominantly prefers to be active during the afternoon (PM) hours with an absolute frequency of 304/666 individuals and a relative frequency by rows of 0.46/1.00. In contrast, *S. roosevelti* predominantly uses night hours with an absolute frequency of 101/123 individuals and relative frequency by rows of 0.82/1.00. Interestingly, both species share the (AM) morning hours as their second choice of temporal preference with *S. nicholsi* having the greater absolute frequency of 214/666 individuals with relative frequency by rows being 0.32/1.00 and *S. roosevelti* having absolute frequency of 16/123 individuals and relative frequency of rows of 0.13/1.00 respectively. In Figure 6, the differences in cumulative proportions of temporal use between species are clear, with *S. roosevelti* having the majority of individuals prevalent at night.

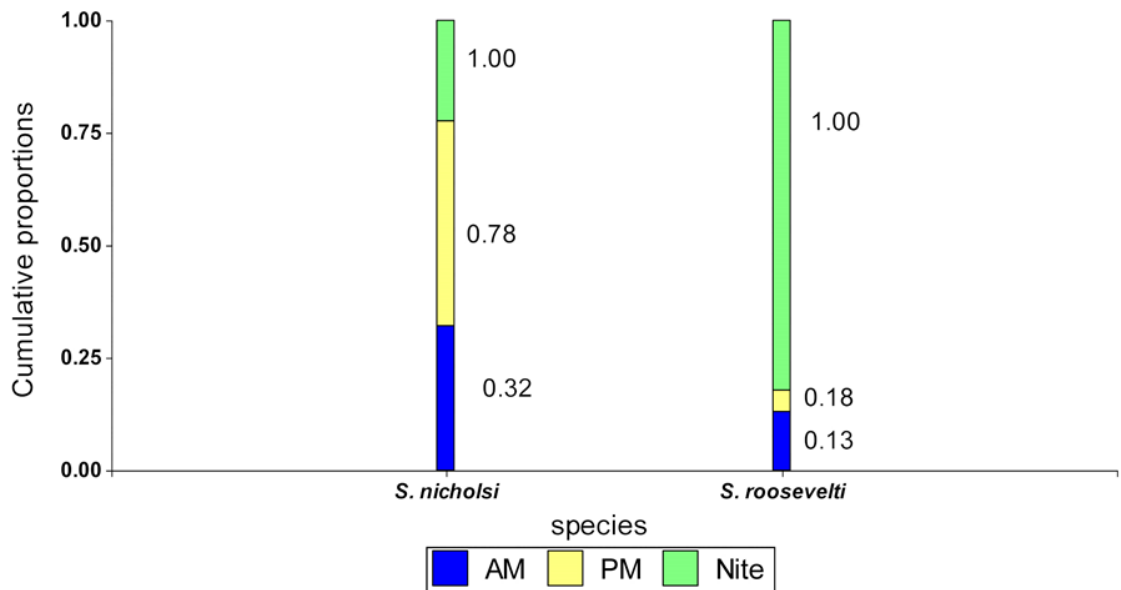


Figure 6. Comparison between species of temporal category selection
AM- Morning, PM- Afternoon and Nite- Night time
Significant differences exist in the temporal category selected by species (Chi-Square, p-value <0.0001). *Sphaerodactylus nicholsi* predominantly selects afternoon (PM) whereas *S. roosevelti* is predominantly active at night time.

Body Condition Index was evaluated by using the independent variable of SVL (mm) and dependent variable of Weight (g) for each species (Table 8, p.88). There is a linear relationship between SVL and Weight in *S. roosevelti* (Figure 7) (Linear Regression, df 2, F 7.01, r^2 0.11; p-value 0.0104).

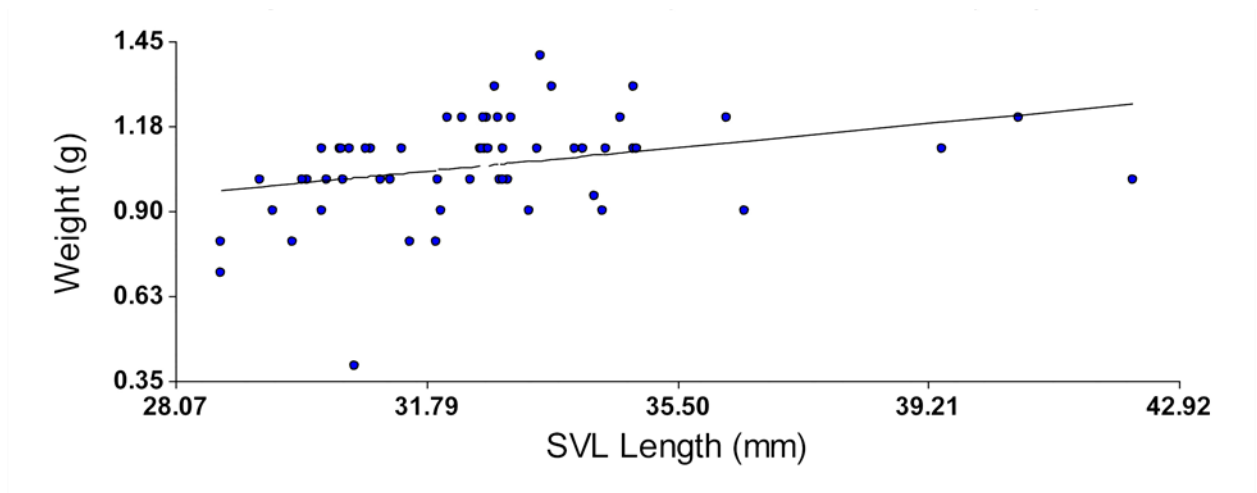


Figure 7. *Sphaerodactylus roosevelti* Body Condition Index (BCI)
Linear Regression demonstrates a linear relationship between Snout Vent Length and weight (p-value 0.0104).

Comparably, when I evaluate *S. nicholsi* BCI (Table 9, p.89 and Figure 8) (Linear Regression, df 1, F 46.59, r^2 0.13; p-value <0.0001) there is a linear relationship between SVL and Weight in this species as well.

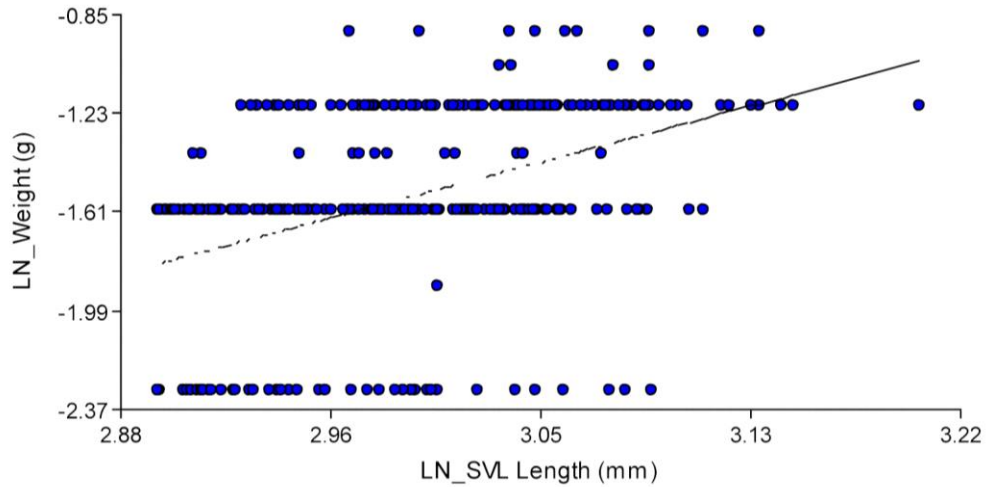


Figure 8. *Sphaerodactylus nicholsi* Body Condition Index (BCI)
Linear Regression demonstrates a linear relationship between Snout Vent Length and weight (p-value <0.0001).

In order to facilitate the representation of the most pertinent categorical data results between *S. nicholsi* and *S. roosevelti* I performed a Multiple Correspondence Analysis (MCA) that included the following variables: Species, Temporal use and Substrate type . My results show that although *S. nicholsi* has a weak association or relationship with morning temporal use (AM), the strongest association or relationship lies with afternoon temporal use (PM) and Leaf litter (LL) as substrate type (Axis 1 and 4 with a cumulative percent of 72.92) (Figure 9). On the other hand, *S. roosevelti* has a strong association or relationship with night time as preferred temporal use and vegetation (V) as most commonly used substrate type.

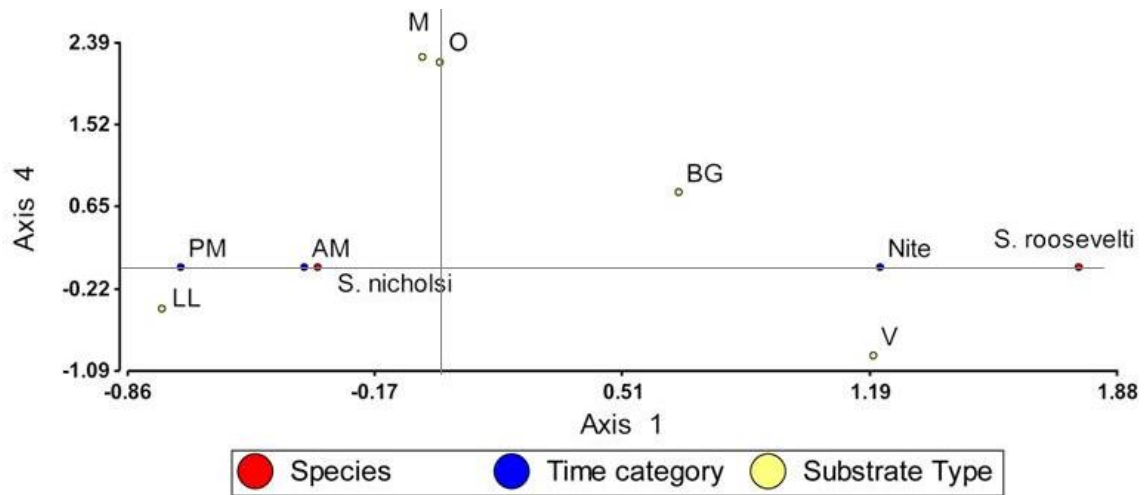


Figure 9. Correspondence Analysis comparing substrate type and temporal category use between species

Sphaerodactylus nicholsi has a strong relationship with afternoon (PM) and Leaf litter (LL), whereas *S. roosevelti* is strongly affiliated with Night time (NITE) and vegetation (V). Axis 1 and 4 cumulative percent 72.92%.

In addition, I conducted a Principal Component Analysis for each species. For *S. nicholsi* I evaluated the associations between Snout-Vent-Length, Tail Length, Leaf litter Depth and Cover (%) with eigenvalue cumulative proportions of 0.63. Figure 10 shows that TL and SVL have a strong, positive association to each other, but are inversely related to cover %. Also, SVL is closely associated to LL depth. However, TL is not associated with Leaf litter depth.

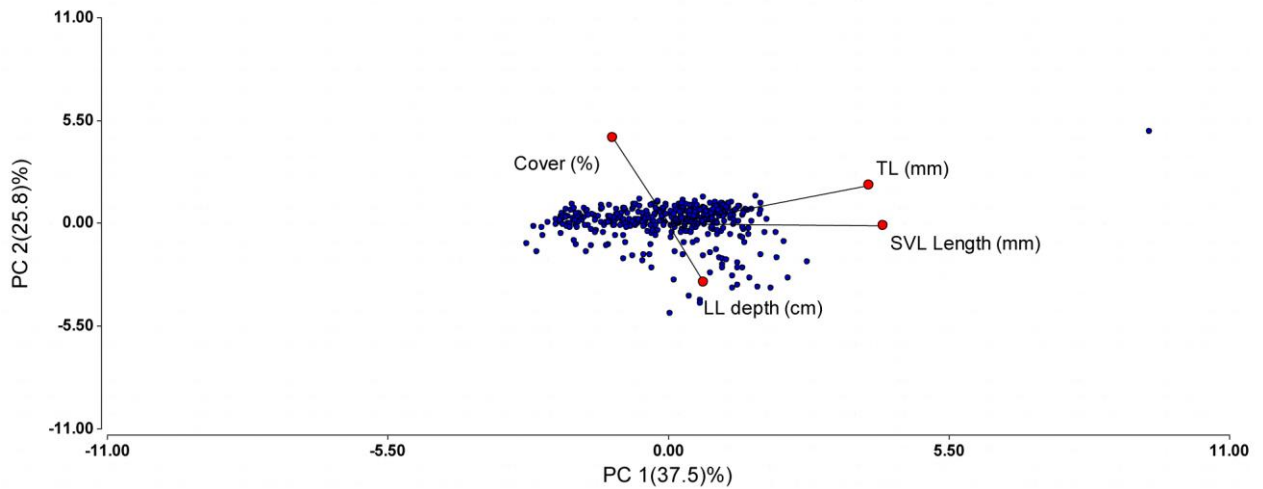


Figure 10. Principal Component Analysis *Sphaerodactylus nicholsi*: Tail Length, Snout Vent Length, Cover and Leaf Litter Depth

Among *S. nicholsi*, Tail length and Snout vent length are closely , positively associated, but inversely related to cover %. Similarly, SVL is closely related to LL depth. (Eigenvalue proportion of 0.63).

For *S. roosevelti* (Figure 11) I evaluated SVL, TL and cover % with an eigenvalue cumulative percent of 0.88. While SVL and TL have a strong, positive association to each other, these morphometric parameters are not associated to cover % in this species.

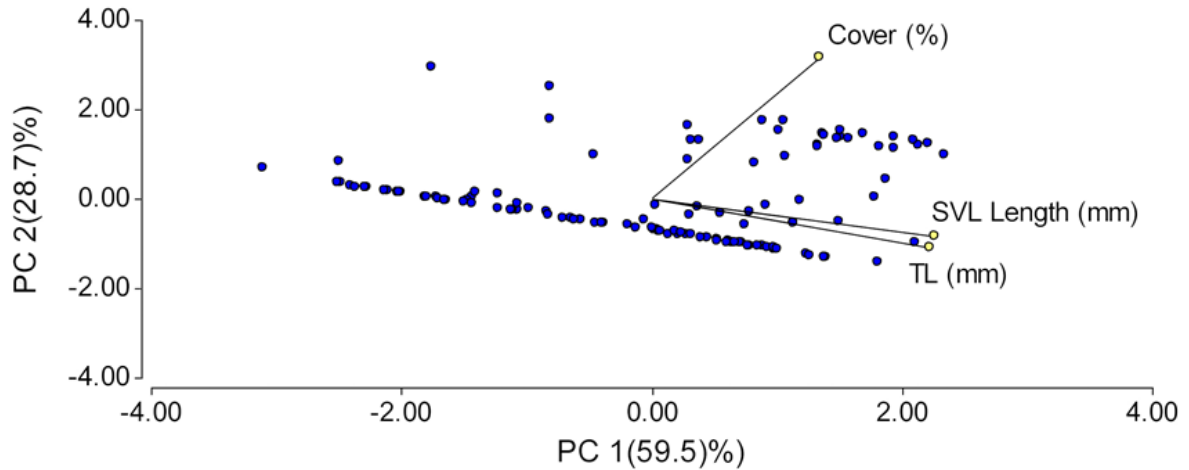


Figure 11. Principal Component Analysis *Sphaerodactylus roosevelti*: Tail Length, Snout Vent Length and Over-story cover

Within *S. roosevelti*, Tail length and Snout vent length are closely , positively associated, but not related to cover %. (Eigenvalue proportion of 0.88).

Temperature preference was evaluated between species. The mean temperature for *S. roosevelti* was 27.96°C (~82.2 °F) and for *S. nicholsi* was 26.77°C (~80.1 °F) (T-Test, T -4.67, p-value <0.0001), (Table 10, p.90 and Figure 12).

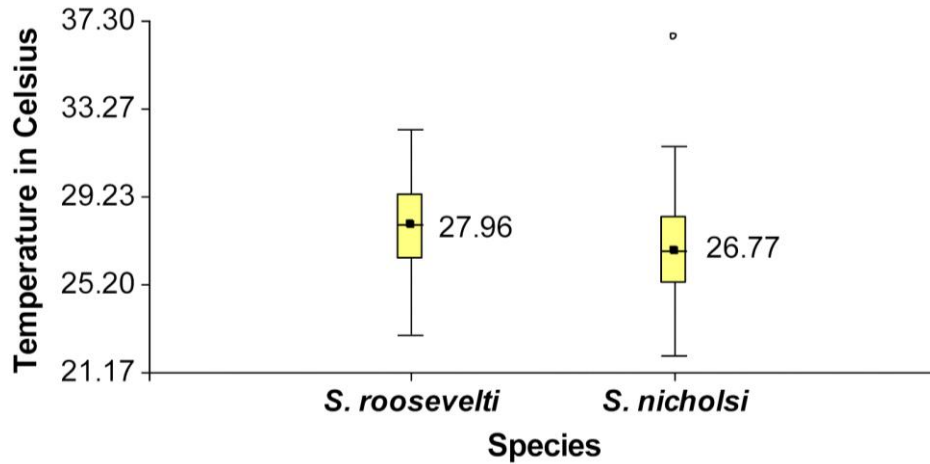


Figure 12. Temperature comparison between *Sphaerodactylus nicholsi* and *S. roosevelti* Mean temperature for captured *S. nicholsi* was statistically lower when compared with *S. roosevelti* (T-Test, p-value <0.0001).

Seasonal reproduction was compared between species taking into account the amount of gravid females present during each season of the year (Fall, Spring, Summer and Winter). There are marked differences in the absolute frequency of gravid females between species. *Sphaerodactylus nicholsi* appear to have a higher frequency of gravid females in winter and summer when compared to *S. roosevelti*. However, (Chi-Square, df 3; p-value 0.4676), no significant differences exists in seasonal reproduction between species.

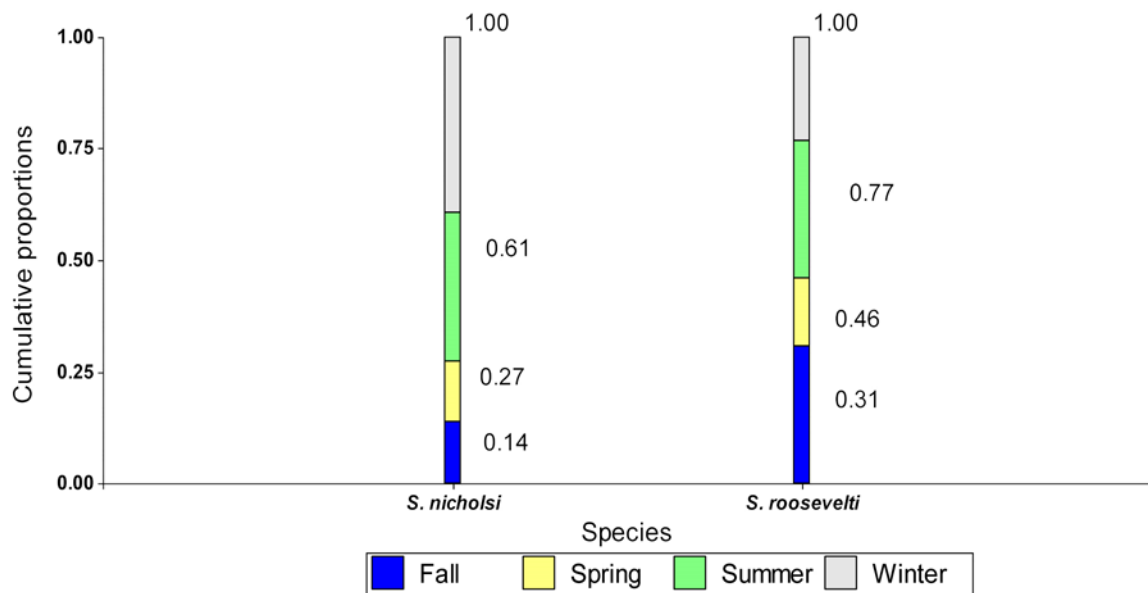


Figure 13. Gravid females of each species found by season of the year. *Sphaerodactylus nicholsi* had a greater amount of gravid females within Winter and Summer season when compared to *S. roosevelti*. However, these differences are not statistically significant (Chi-Square, p-value 0.476).

The influence of lunar phases on *S. roosevelti* presence was evaluated by taking into account the four main phases of the moon (First Quarter, Full Moon, Last Quarter and New Moon). The greatest absolute frequency (41) of *S. roosevelti* was found during the new moon versus the lowest absolute frequency (16) found during last quarter. The first quarter (21) and full moon (23) lunar phases had similarly intermediate absolute frequencies. I can state that lunar phases have an influence on *S. roosevelti* prevalence (Chi-Square, df 3; p-value 0.0027) (Table 23, p.103).

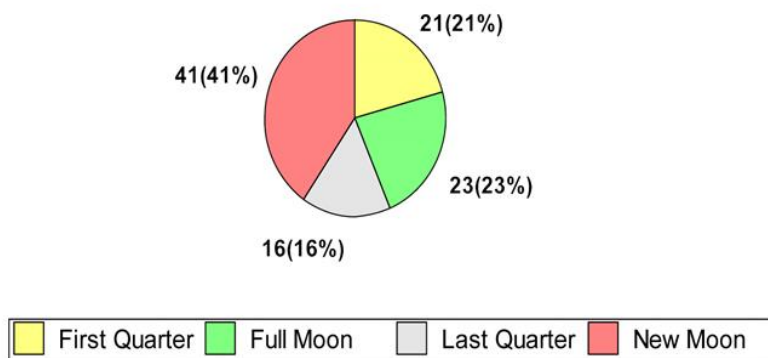


Figure 14. *Sphaerodactylus roosevelti* prevalence by lunar phases
 There is an increased prevalence of individuals during the new moon phase than any other phase (Chi-Square, p-value 0.0027).

Intraspecific Comparison of Microhabitat and Morphometrics Between Age Categories

S. nicholsi

Substrate type use was evaluated between *S. nicholsi*'s age categories (Hatchling (H), Juvenile (JV), Adult (A)). Substrate type was categorized as: Bare ground (BG), Leaf Litter (LL), Mixed (M), Other (O) and Vegetation (V). Significant differences exist in the substrate type preferred between age categories of *S. nicholsi* (Chi –Square, df 8; p-value <0.0001) (Table 11, p.91 and Figure 15). Although all age categories selected Leaf litter (LL) as preferred substrate use with relative frequencies of rows being 0.48 for Adults, 0.62 for Hatchlings, and 0.71 for Juveniles, the differences lie in their second most commonly used substrate type (Table 11). The relative frequencies by rows were 0.24 for vegetation in adults, 0.16 for Bare ground in Hatchlings, and 0.12 for mixed in Juveniles. Figure 15 illustrates the apparent differences in the cumulative proportions of substrates: mixed, other, bare ground and vegetation between the different age categories of *S. nicholsi*.

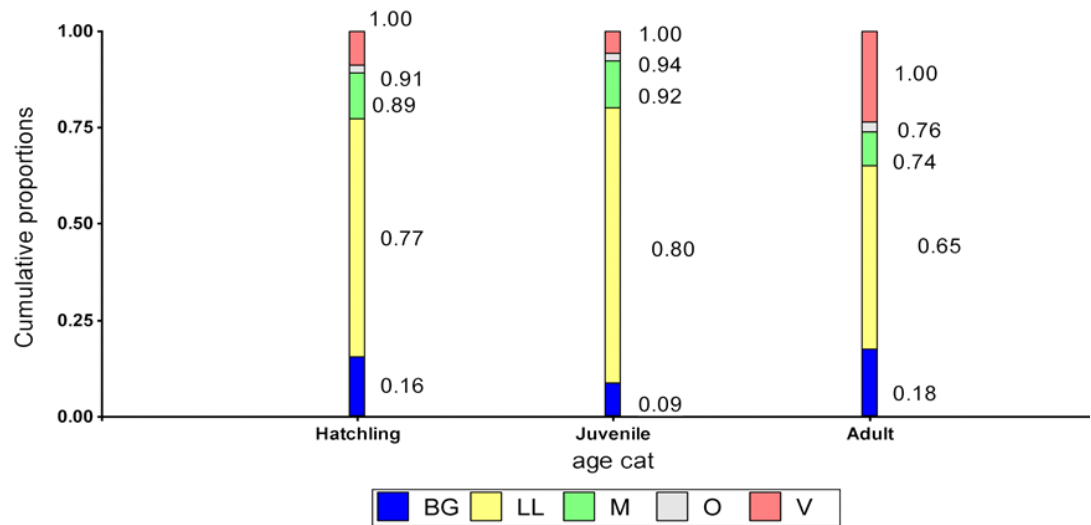


Figure 15. Substrate selection comparison between age categories of *Sphaerodactylus nicholsi*

BG- Bare Ground, LL-Leaf litter, M-Mixed, O-Other and V-Vegetation
Significant differences exist in the substrate type selected by age category (Chi-Square, p-value <0.0001). The second most commonly selected substrate for Adults was vegetation, bare ground for hatchlings and mixed for juveniles.

In addition, over story cover use was compared between *S. nicholsi* age categories (Table 12, p.92 and Figure 16). Adults had a significantly lower mean for over- story use (59.64% and SD± 41.26) than both hatchlings (85.25% and SD ± 24.65) and Juveniles (84.64% and SD±25.01) who were not significantly different between each other (Table 12). (Non-Parametric Kruskal Wallis Test, p-value <0.0001).

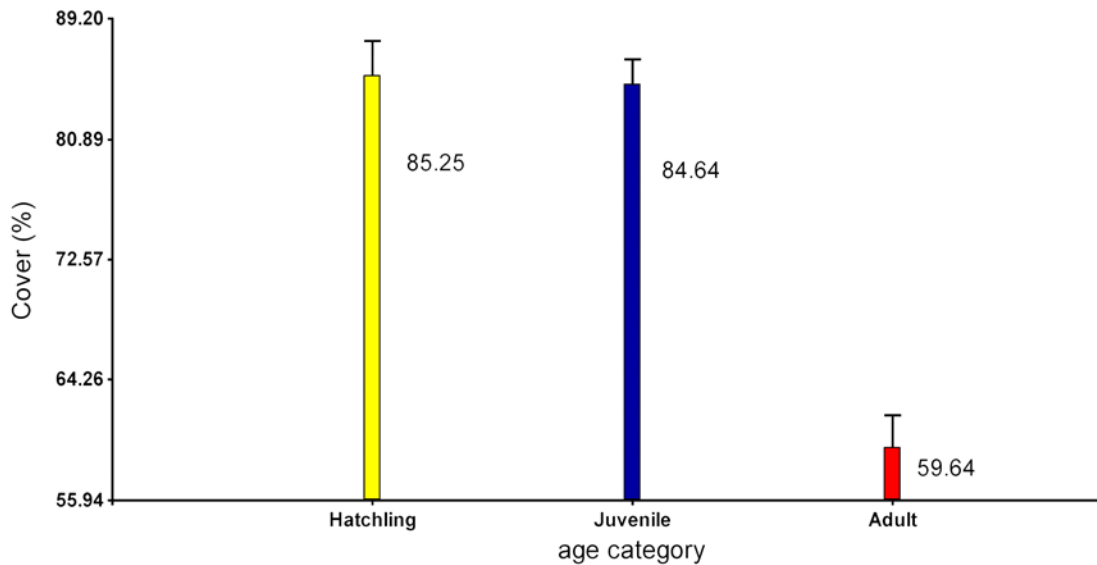


Figure 16. Over story cover (%) selection by age categories of *Sphaerodactylus nicholsi*

Significant differences exist between over story cover selection and age categories (Non-Parametric Kruskal Wallis Test, p-value <0.0001). Adults had the lowest percent mean of over story cover when compared with hatchlings and juveniles.

Furthermore, no significant differences exist in the depth (cm) of Leaf Litter used by age categories of *S. nicholsi* (Non-Parametric Kruskal Wallis Tests, p-value 0.2031) (Table 13, p.93 and Figure 17).

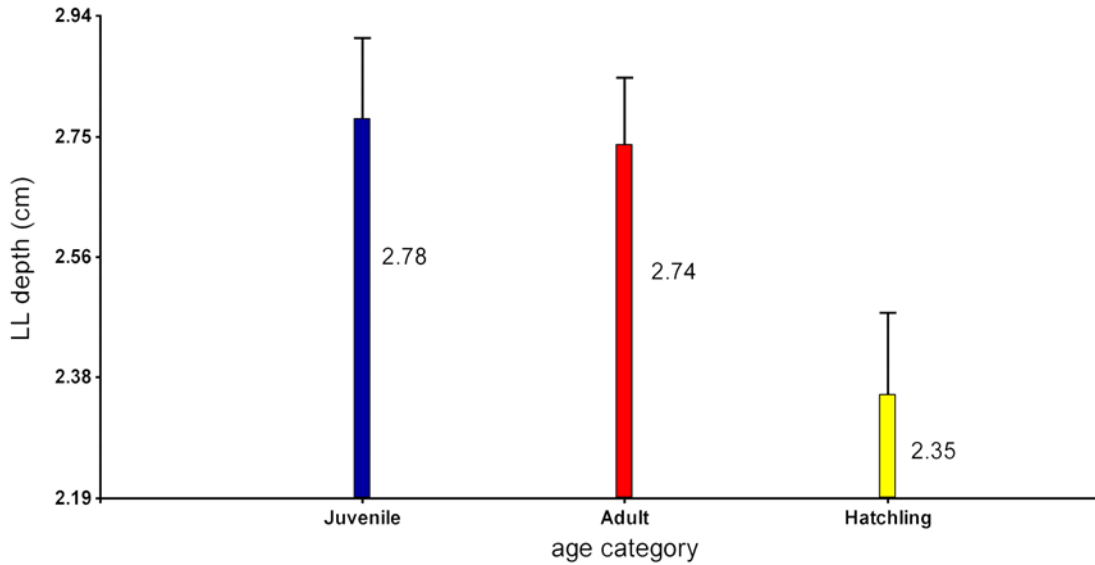


Figure 17. Leaf Litter depth (cm) selection comparison by age categories of *Sphaerodactylus nicholsi*

No significant differences exist in leaf litter depth selection between age categories (Non-Parametric Kruskal Wallis Test, p-value 0.2031).

I compared *S. nicholsi*'s age category morphometrics, such as Snout Vent Length (mm), Tail Length (mm) and Weight (g), to elucidate age differences (Table 14, p.94 and Figures 18 A, B ,C). Significant differences exist in morphometrics between age categories of *S. nicholsi*. (Non-Parametric Kruskal Wallis Test for SVL (p-value <0.0001), TL (p-value <0.0001) and Weight (p-value <0.0001)). The means for SVL (20.08 mm and SD \pm 1.22), TL (16.97 mm and SD \pm 6.23) and Weight (0.23 g and SD \pm 0.07) are greater for Adult category than Juveniles and Hatchling. The means for Juveniles are as follows: SVL (15.90 mm and SD \pm 1.46), TL (14.29 mm and SD \pm 3.74) and Weight (0.14 g and SD \pm 0.05). Hatchlings had the lowest values for morphometrics: SVL (11.62 mm and SD \pm 0.83), TL (9.15 mm and SD \pm 2.74) and Weight (0.10 g or less).

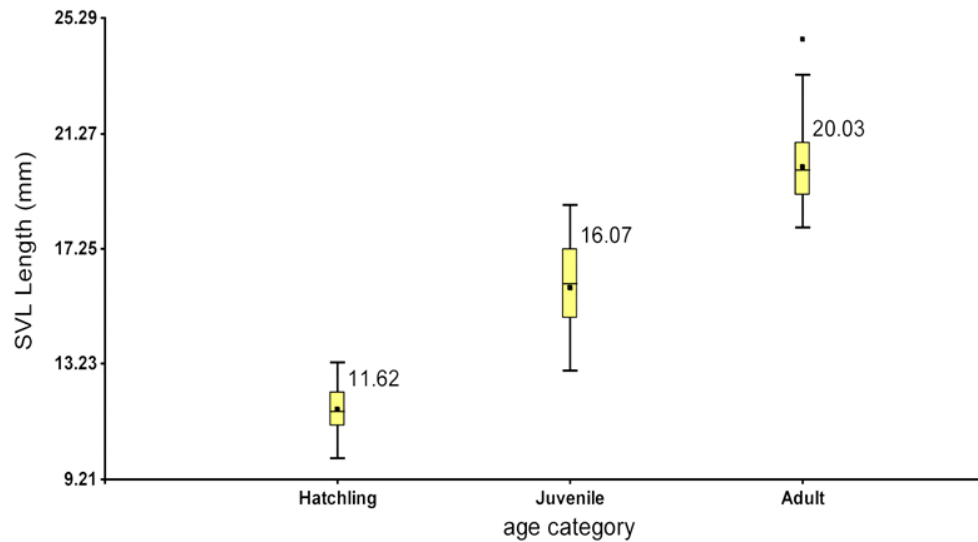


Figure 18A. Snout Vent length comparison by age categories of *Sphaerodactylus nicholsi* Significant differences exist in the SVL mean between age categories (Non-Parametric Kruskal Wallis Test, p-value <0.0001).

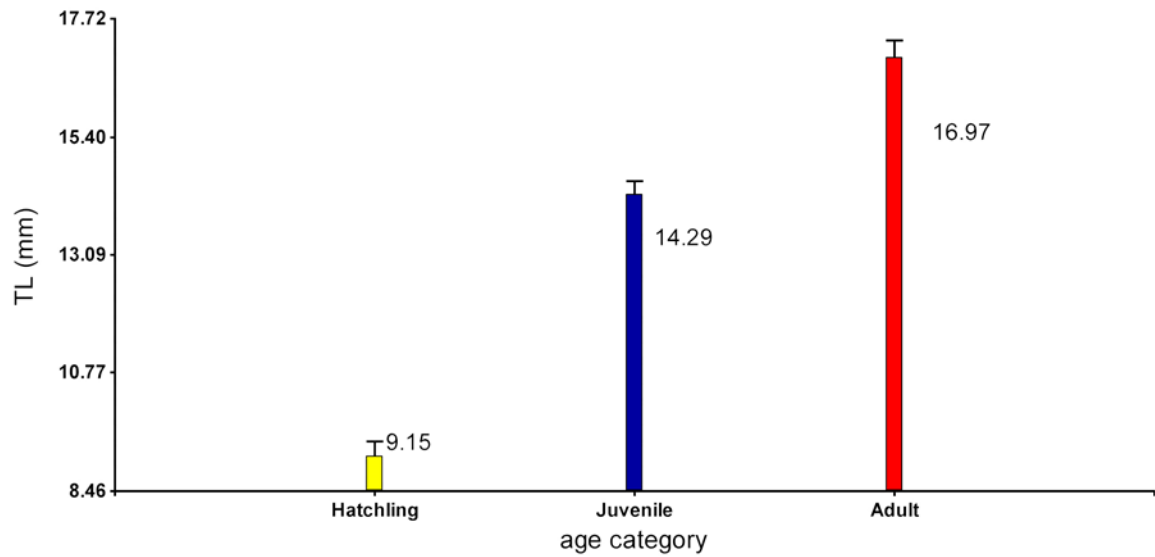


Figure 18B. Tail length (mm) comparison by age categories of *Sphaerodactylus nicholsi*

Significant differences exist in the Tail length mean by age categories (Non-Parametric Kruskal Wallis Test ,p-value <0.0001).

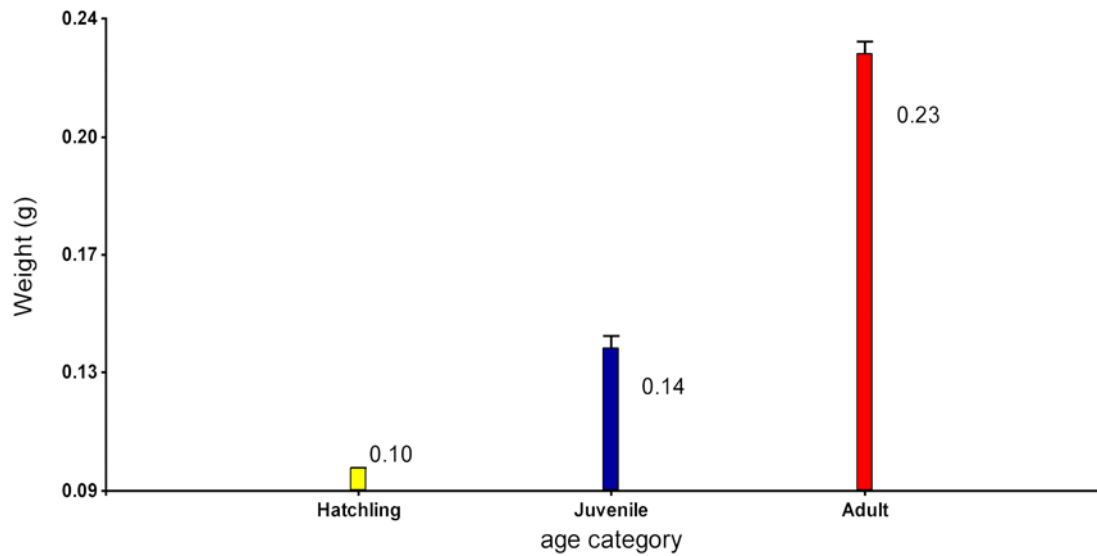


Figure 18C. Weight (g) comparison by age categories of *Sphaerodactylus nicholsi*

Significant differences exist in weight mean by age categories (Non-Parametric Kruskal Wallis Test, p-value <0.0001).

Differences in temporal use were evaluated between *S. nicholsi*'s age categories (Hatchling (H), Juvenile (JV), Adult (A)). Temporal use was categorized as follows: Morning (AM), Afternoon (PM), and Night. Significant differences exist in the type of temporal use preferred between age categories of *S. nicholsi* (Chi-Square, df 4; p-value <0.0001) (Table 15, p.95). Although all age categories selected afternoon (PM) as preferred temporal use with relative frequencies of rows being 0.39 for Adults, 0.53 for Hatchlings and 0.54 for Juveniles; the differences lie in their second most commonly used temporal category (Table 15 and Figure 19). The relative frequencies by rows were 0.31 for night (Adults), 0.32 (Hatchlings) and 0.36 (Juvenile) for morning (AM).

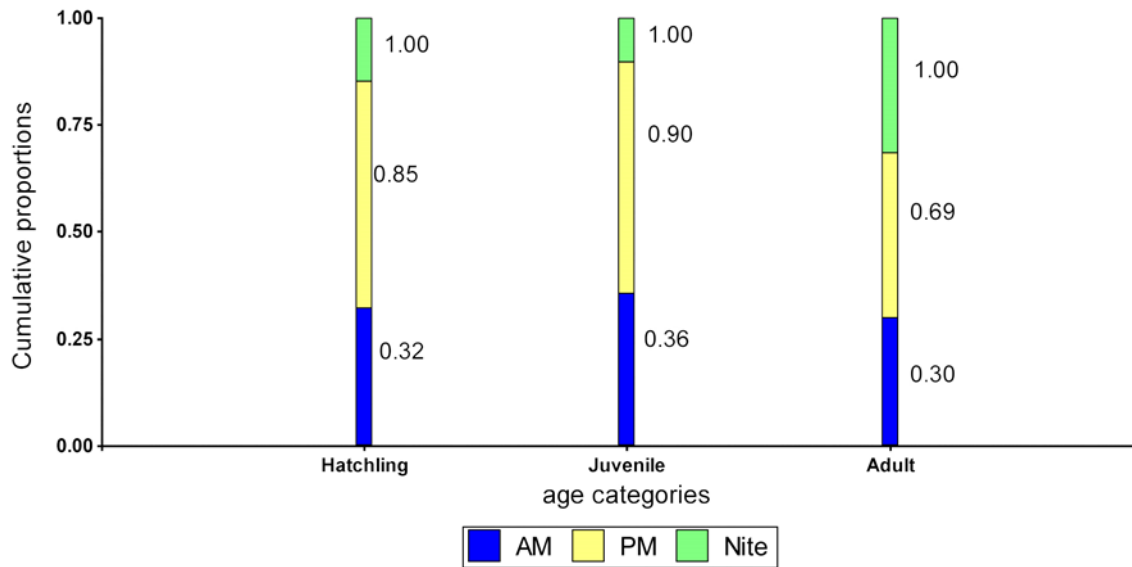


Figure 19. Temporal category selection by age categories of *Sphaerodactylus nicholsi*

AM-morning, PM- Afternoon and Nite- Night

Significant differences exist in the second most prevalent temporal category selected (Chi-Square, p-value <0.0001). Adults selected night whereas hatchlings and juveniles selected morning time.

Significant differences exist in seasonal prevalence between age categories of *S. nicholsi* (Chi-Square, df 6; p-value <0.0001) (Table 20, p. 100 and Figure 20). Adults had an increased prevalence during winter (W) with an absolute frequency of 121/357 individuals. Both Hatchlings and Juveniles were most prevalent during fall season (F) with an absolute frequency of 29/102 (H) and 70/207 (JV).

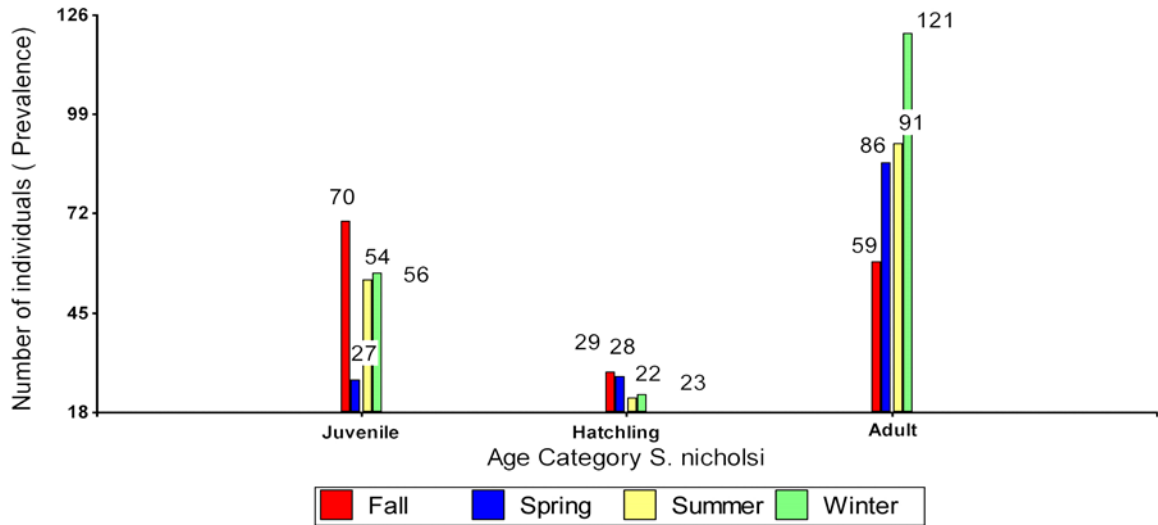


Figure 20. Prevalence of *Sphaerodactylus nicholsi* age categories during every season of the year

There are significant differences in the prevalence of each category by season (Chi-Square, p-value <0.0001). Hatchlings and Juveniles were most prevalent during Fall, whereas Adults were more prevalent during Winter.

S. roosevelti

Substrate type use was compared between *S. roosevelti* age categories (Hatchling (H), Juvenile (JV), Adult (A)). Substrate type was categorized as follows: Bare ground (BG), Leaf Litter (LL), Mixed (M), Other (O) and Vegetation (V). Significant differences exist in the type of substrate type preferred between age categories of *S. roosevelti* (Chi-Square, df 8; p-value 0.0175) (Table 16, p.96). Adults and Juveniles selected vegetation as their preferred substrate type with a relative frequency of rows being 0.56 (A) and 0.75 (JV). In contrast, hatchlings selected bare ground (BG) as most commonly used substrate with a relative frequency of rows being 0.52. Figure 21 illustrates the apparent differences in the cumulative proportions of substrates between the different age categories of *S. roosevelti*.

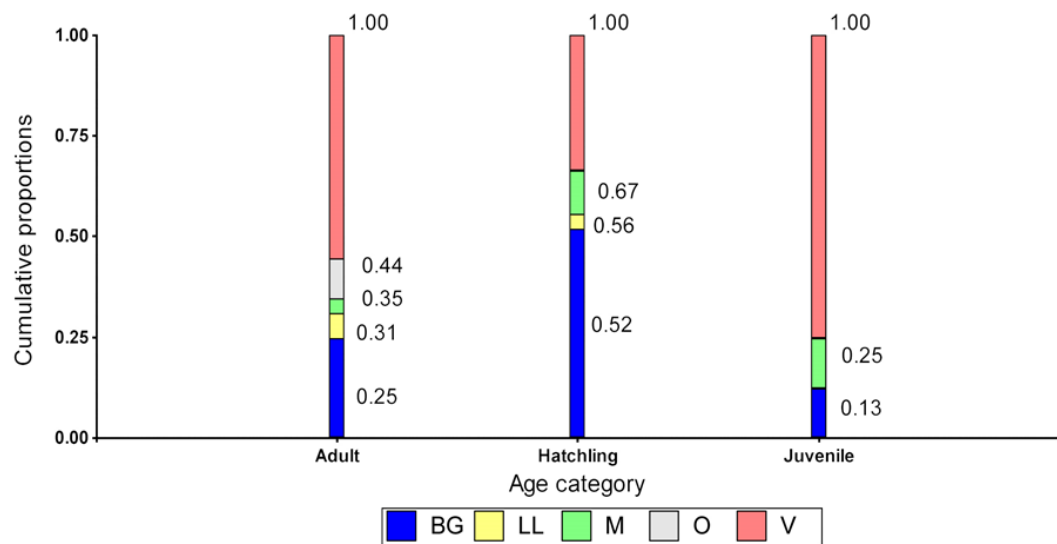


Figure 21. Substrate selection by age categories of *Sphaerodactylus roosevelti* Significant differences exist between substrate type selected by age category (Chi-Square, p-value 0.0175). Adults and Juveniles selected vegetation, while hatchlings selected bare ground.

In addition, over story cover use was compared between *S. roosevelti* age categories (Table 17, p.97). Significant differences exist in the percent of over story cover used by age categories of *S. roosevelti* (Non-Parametric Kruskal Wallis, p-value 0.0373). Adults had a significantly higher mean (29.09 % and SD+/- 38.24) than hatchlings (10.44 % and SD± 28.14) but Juveniles (14.53 % and SD ±29.83) were not significantly different from other categories (Table 17). Figure 22 clearly illustrates the variation of mean between adult and hatchling categories.

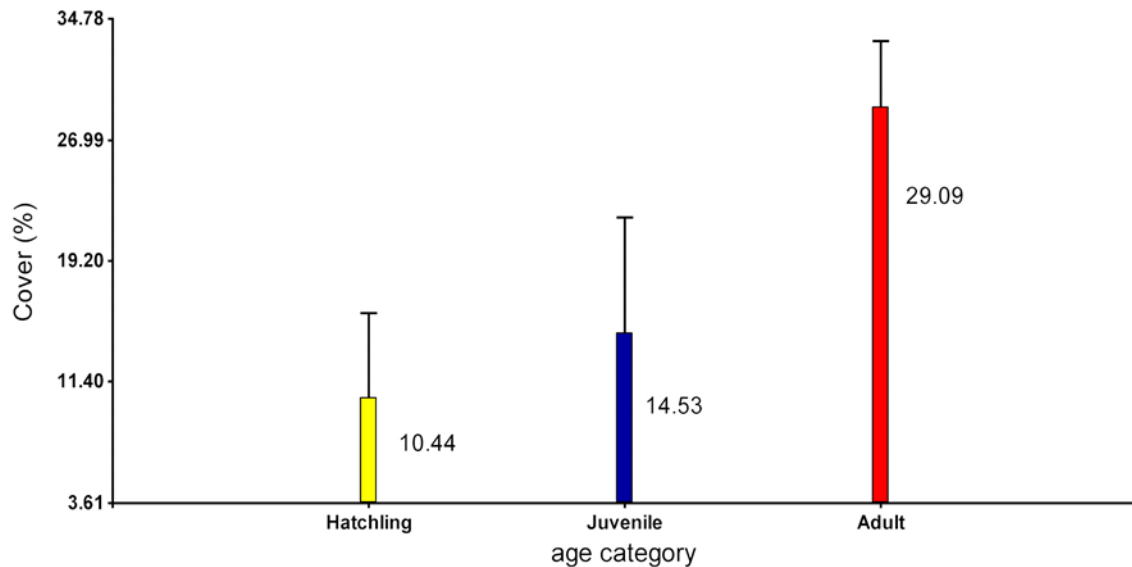


Figure 22. Over story cover (%) selection by age categories of *Sphaerodactylus roosevelti* Adults had a significantly higher over story cover mean, than hatchlings or juveniles (Non-Parametric Kruskal Wallis Test, p-value 0.0373).

Furthermore, no significant differences exist in the depth (cm) of Leaf Litter used by age categories (Non-Parametric Kruskal Wallis Test, p-value 0.7143) (Table 18, p.98 and Figure 23).

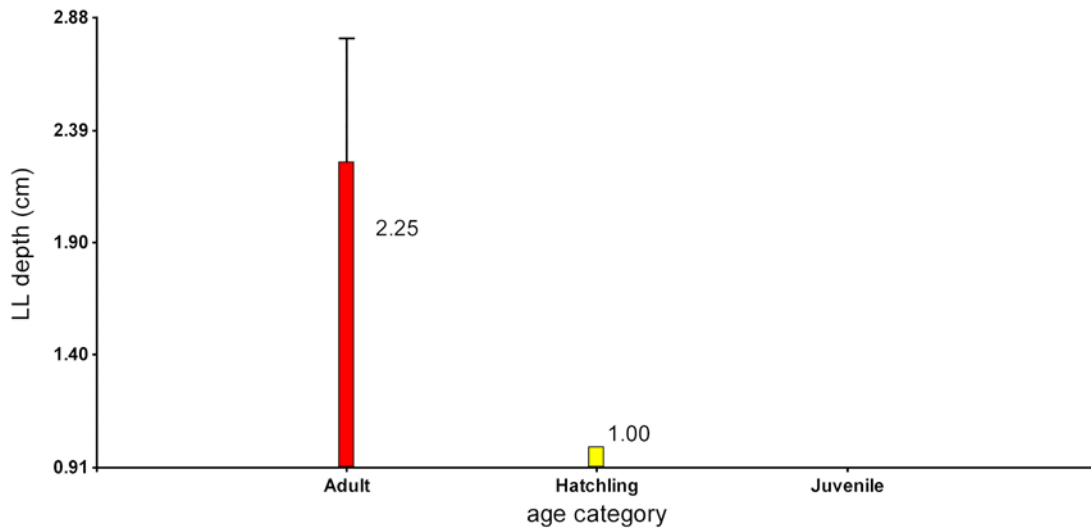


Figure 23. Leaf Litter Depth (cm) selection by age categories of *Sphaerodactylus roosevelti*
No significant differences exist in the leaf litter depth selection between age categories (Non-Parametric Kruskal Wallis Test, p-value 0.7143).

I compared *S. roosevelti* age category morphometrics such as Snout Vent Length (mm), Tail Length (mm) and Weight (g) to elucidate age differences (Table 19, p.99 and Figure 24A and 24B). Significant differences exist in morphometrics between age categories of *S. roosevelti* (Non-Parametric Kruskal Wallis test- SVL (p-value <0.0001), TL (p-value <0.0001) and Weight (p-value <0.0001)). The means for SVL (32.19 mm and SD± 3.74), TL (31.06 mm and SD±7.87) and Weight (1.02 g and SD ±0.25) are greater for Adult category than Juveniles and Hatchling. The means for Juveniles are as follows: SVL (25.26 mm and SD ±1.62), TL (26.18 mm and SD ±8.20) and Weight (0.50 g and SD ±0.20). Hatchlings had the lowest values for morphometrics: SVL (19.18 mm and SD±2.13), TL (17.26 mm and SD±5.23) and Weight (0.22 g and SD± 0.07).

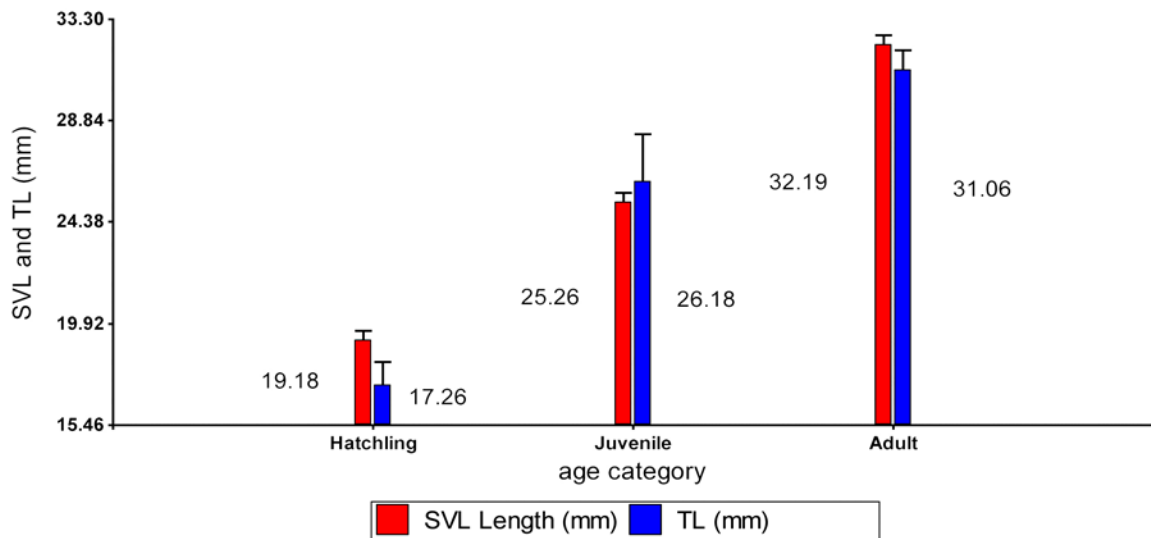


Figure 24A. Snout -vent and Tail length (mm) comparison between age categories of *Sphaerodactylus roosevelti*

Significant differences exist in the SVL and TL mean between age categories (Non-Parametric Kruskal Wallis Test, p-value <0.0001).

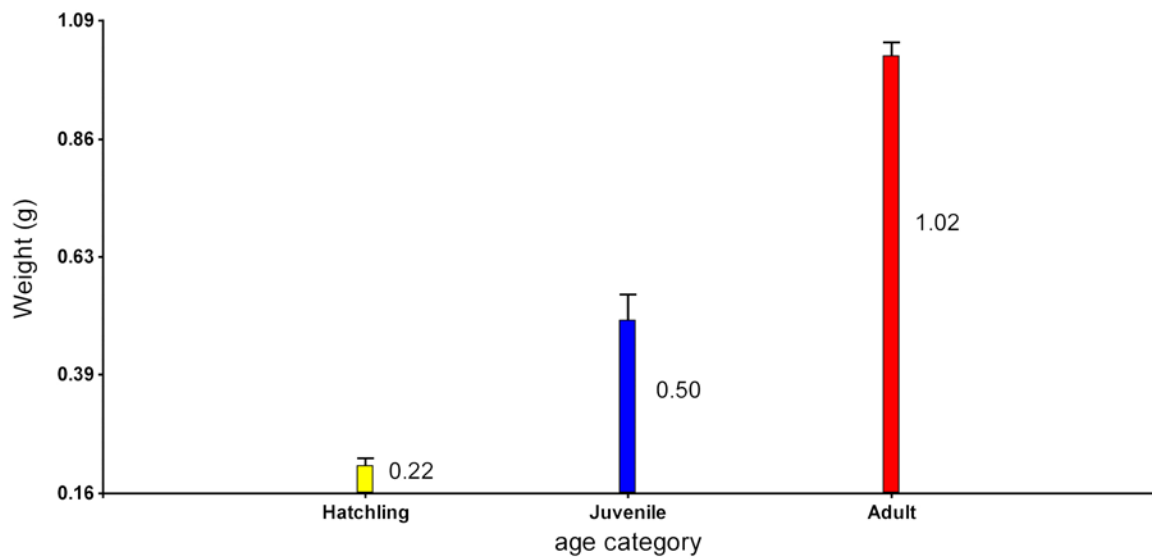


Figure 24B. Weight (g) comparison between age categories of *Sphaerodactylus roosevelti*

Significant differences exist between the mean weight by age categories (Non-Parametric Kruskal Wallis Test, p-value <0.0001).

Temporal use was categorized as follows: Morning (AM), Afternoon (PM), and Night (NITE). No significant differences exist in the type of temporal use preferred between age categories of *S. roosevelti* (Chi-Square, df 4; p-value 0.3296) (Figure 25). All age categories selected night as preferred temporal use with relative frequencies of rows being 0.77 for Adults, 0.93 for Hatchlings, and 0.88 for Juveniles.

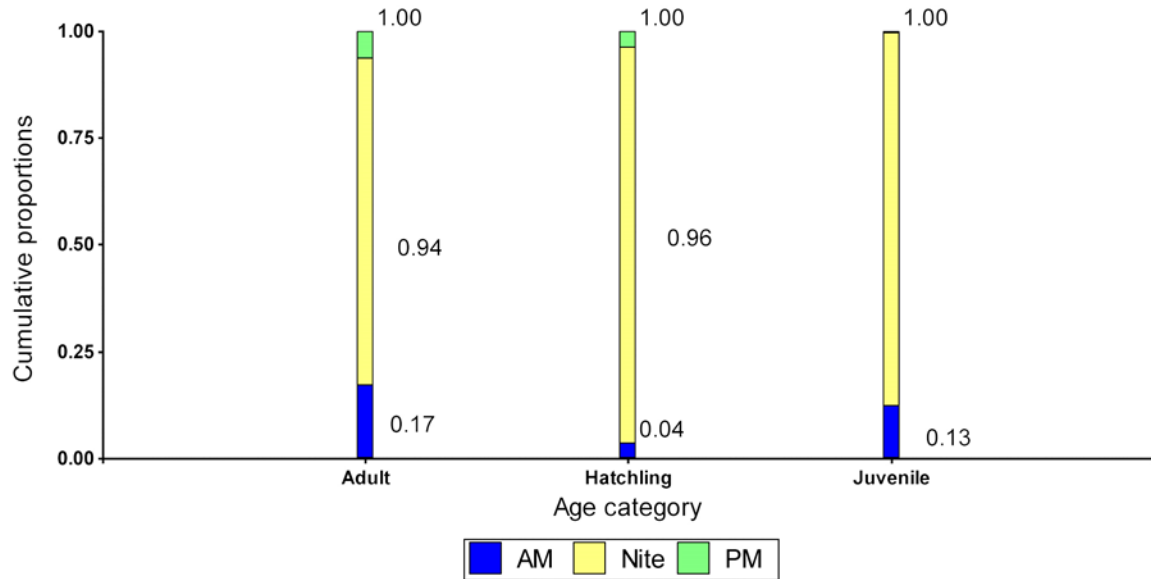


Figure 25. Comparison between age categories of *Sphaerodactylus roosevelti* and temporal category selection (AM- Morning, Nite- night time, PM- afternoon) No statistical differences were found between age categories and temporal selection (Chi-Square,p-value 0.3296).

Significant differences exist in seasonal prevalence between age categories of *S. roosevelti* (Chi-Square, df 6; p-value 0.0323) (Table 21, p.101 and Figure 26). Adults had an increased prevalence during fall (F) with an absolute frequency of 29/81 individuals. On the other hand, hatchlings were most prevalent during the spring (SP) with an absolute prevalence of 11/27 individuals and Juveniles were most prevalent during fall season (F) with an absolute frequency of 8/16 individuals.

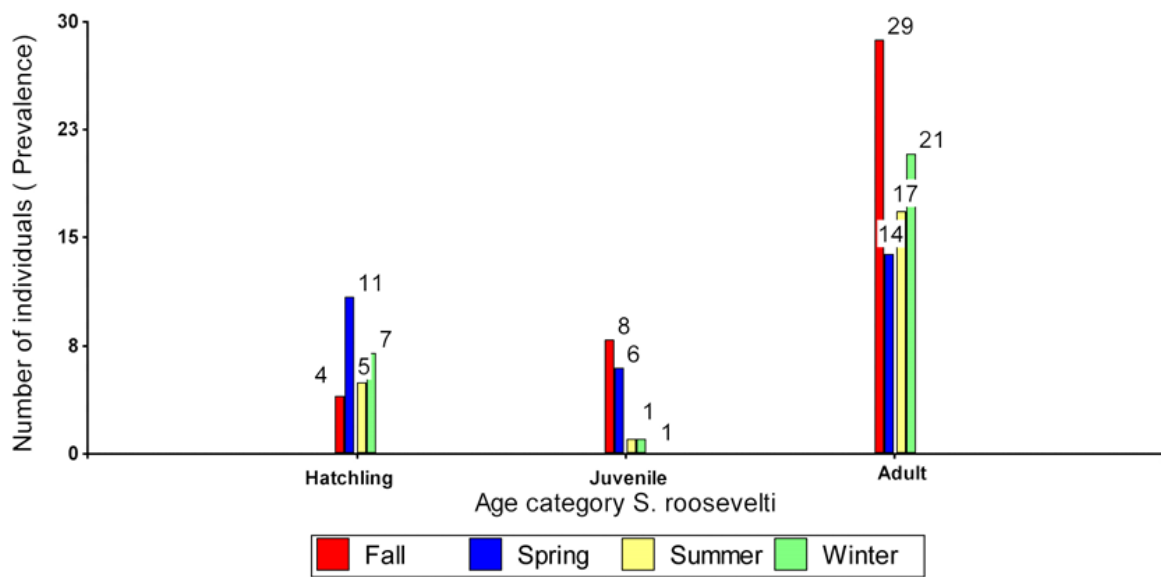


Figure 26. Prevalence of *Sphaerodactylus roosevelti* age categories during every season of the year

There are significant differences in the prevalence of each category by season (Chi-Square, p-value 0.0323). Adults and Juveniles were most prevalent during Fall, whereas Hatchlings were more prevalent during Spring.

I compared male and female *S. roosevelti* over story cover (%) and leaf litter depth (cm) to elucidate gender differences in microhabitat use. No significant differences exist in the use of overstory cover (T- test, p-value 0.5333) (Figure 24), and Leaf Litter depth (cm) (T- test, p-value 0.7712) (Figure 27) between male and female *S. roosevelti*. Although the means of over-story cover slightly vary by gender: male (27.09% and $SD \pm 37.63$) and female (32.47% and $SD \pm 39.87$) these numbers do not vary enough to statistically prove significant difference.

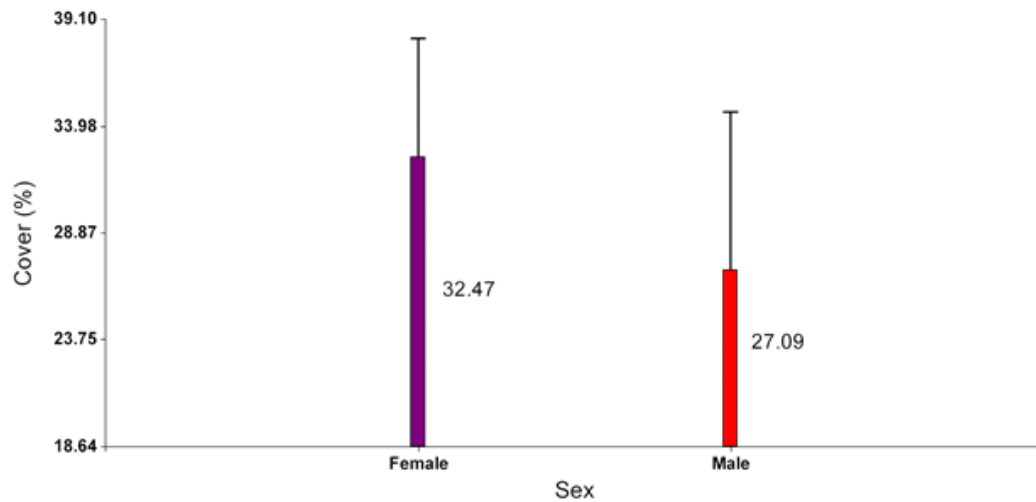


Figure 27. Comparison of over story cover selection by gender of *Sphaerodactylus roosevelti*

No statistical differences were found in the selection of over story cover by gender (T-test, p-value 0.5333).

Similarly, Figure 28 also appears to demonstrate disparity in the means of leaf litter depth between gender, male (1.5 cm and $SD \pm 0.71$) and female (2.63 cm and $SD \pm 1.49$). However, these differences are not considered significant.

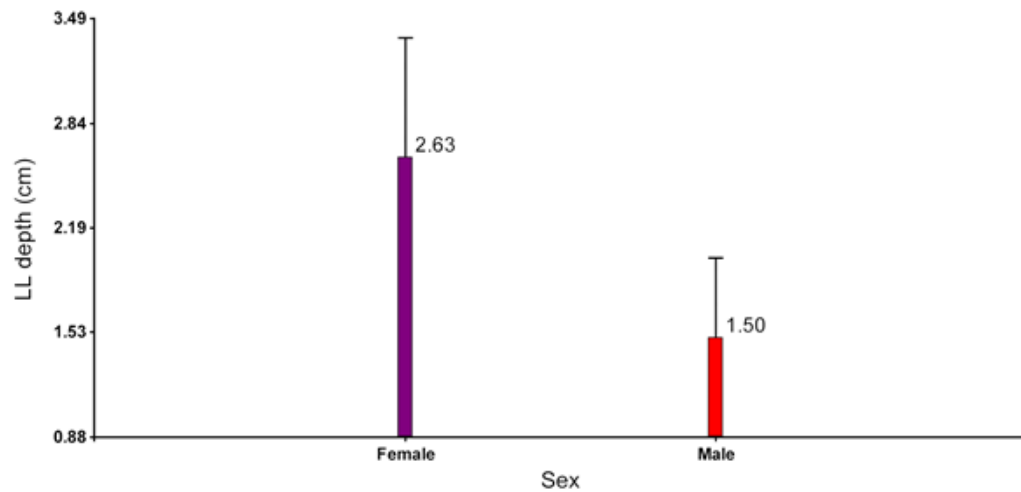


Figure 28. Comparison of leaf litter depth (cm) selection by gender of *Sphaerodactylus roosevelti*

No statistical differences were found between leaf litter depth selection and gender (T- test, p-value 0.7712).

In addition, male and female *S. roosevelti* morphometrics such as Snout Vent Length (mm), Tail Length (mm) and Weight (g) were compared to elucidate gender differences. No significant differences exist in Snout-Vent- Length (Kruskall Wallis, p-value 0.2184) or Weight (Kruskall Wallis, p-value 0.0974) between the sexes of *S. roosevelti*. Upon review of Table 22 (p.102) and the accompanying Figures (29A and 29B), notice that although the means of SVL and Weight slightly vary by gender: male (33.25 SVL mm/1.11 g weight) and female (32.36 SVL mm/ 1.04 g weight) these numbers do not vary enough to statistically prove significant difference. However, for TL (Kruskall Wallis, p-value 0.0361), significant differences do exist between male and female *S. roosevelti* and tail length (mm). Upon review of Table 22 and Figure 29A, observe that the means between male and female are in fact noticeably different with the male having the longest mean of tail length at 33.91 mm (SD± 5.78) and the female at 30.28 mm (SD±8.43) respectively.

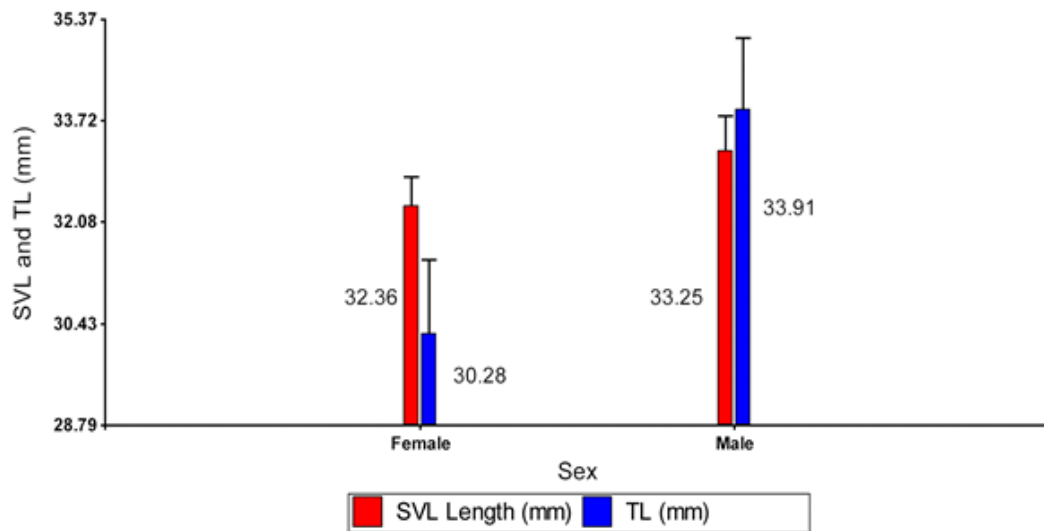


Figure 29A. Comparison of Snout Vent Length and Tail Length between gender of *Sphaerodactylus roosevelti* No statistical differences exist in the SVL between sexes (Kruskall Wallis, p-value 0.2184). However, Tail length between genders does vary (Kruskall Wallis, p-value 0.0361), with males having longer tails than females.

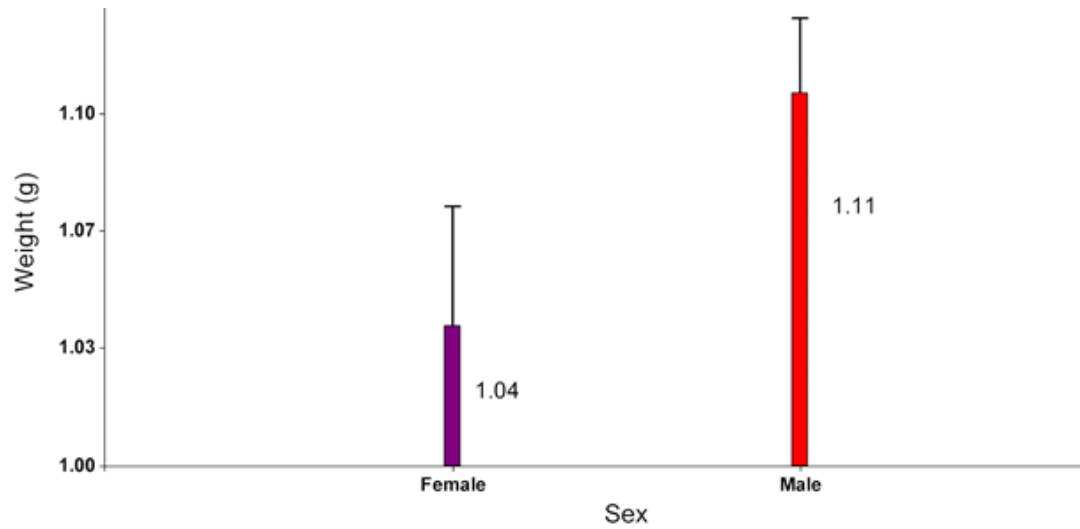


Figure 29B. Comparison of weight (g) between genders of *Sphaerodactylus roosevelti*
No significant differences were found in weight by gender (Kruskall Wallis, p-value 0.0974).

Differences between *S. roosevelti* gender preference of substrate type and temporal use were evaluated. Substrate type was categorized as follows: Bare ground (BG), Leaf Litter (LL), Mixed (M), Other (O) and Vegetation (V). Temporal categories were divided as follows: AM (6:00 a.m.-12:00 p.m.), PM (12:01-6:44 p.m.) and Night (6:45pm-12am). No differences exist between male and female *S. roosevelti* and their substrate type use (Chi-Square, df 4;p-value 0.7355) and temporal use (Chi-Square, df 2;p-value 0.8040) . Both male and female favored the selection of vegetation as substrate type. The females had the greatest absolute frequency of vegetation (V) use (25/50 individuals) while males had 15/25 individuals respectively Similarly, both sexes also selected Bare ground (BG) as their second preference of substrate type. The females once again having the greatest absolute frequency of this category (13/50). On the other hand, males had an absolute frequency of 6/25 individuals.

Likewise, both genders share their top preference for temporal use as well with night time being the most common time to be active. The absolute frequencies for females being 36/50 individuals. Similarly, males had an absolute frequency of 19/25 individuals. Interestingly enough, both sexes also share the second preferred temporal category being morning category (AM). The absolute frequencies of AM for females being 10/50 individuals and males 5/25. Furthermore, Figures 30 and 31 illustrate the almost uniform cumulative proportions between genders and their preference for substrate type and temporal use thus supporting my results that no significant differences exist between genders of *S. roosevelti* and these parameters.

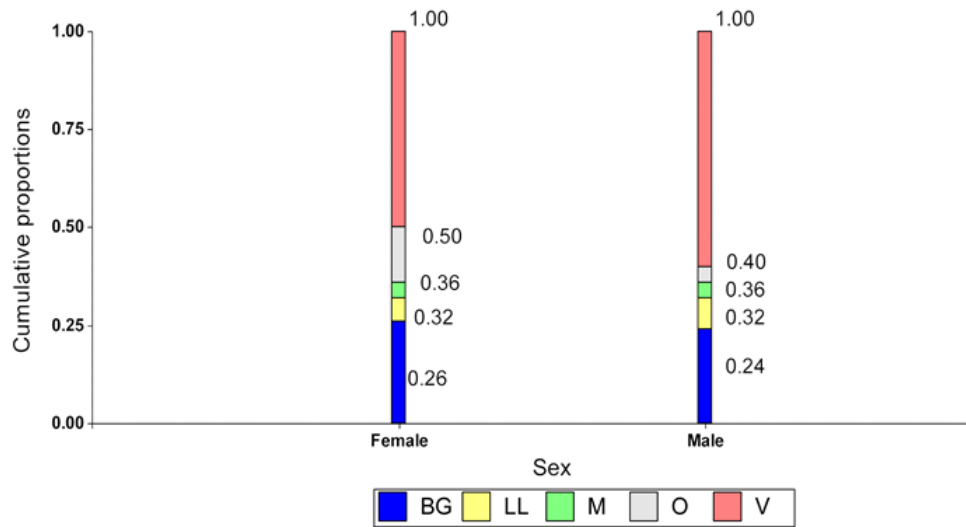


Figure 30. Comparison of male and female *Sphaerodactylus roosevelti* substrate type selection

BG- Bare ground, LL- Leaf Litter, M-Mixed, O-Other and V- Vegetation

No significant differences exist between the type of substrate selected by genders (Chi-Square, p-value 0.7355).

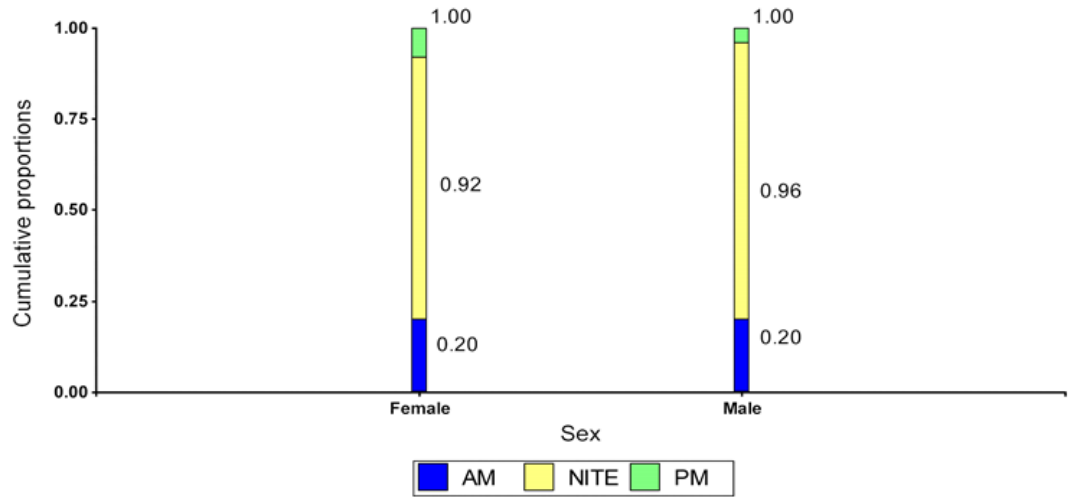


Figure 31. Comparison of male and female *Sphaerodactylus roosevelti* temporal category selection

AM-Morning, PM-Afternoon and NITE-night time

No significant differences were found in the temporal category selected by gender (Chi-Square, p-value 0.840).

No significant differences were found between male and female of *S. roosevelti* and lunar phase prevalence (Chi Square, df 3; p-value 0.6908). The absolute frequencies for both male (13/25) and female (24/50) were greatest during new moon lunar phase. Furthermore, Figure 32 illustrates this idea very clearly. Upon review, the cumulative proportions of prevalence for each species during each lunar phase is strikingly similar.

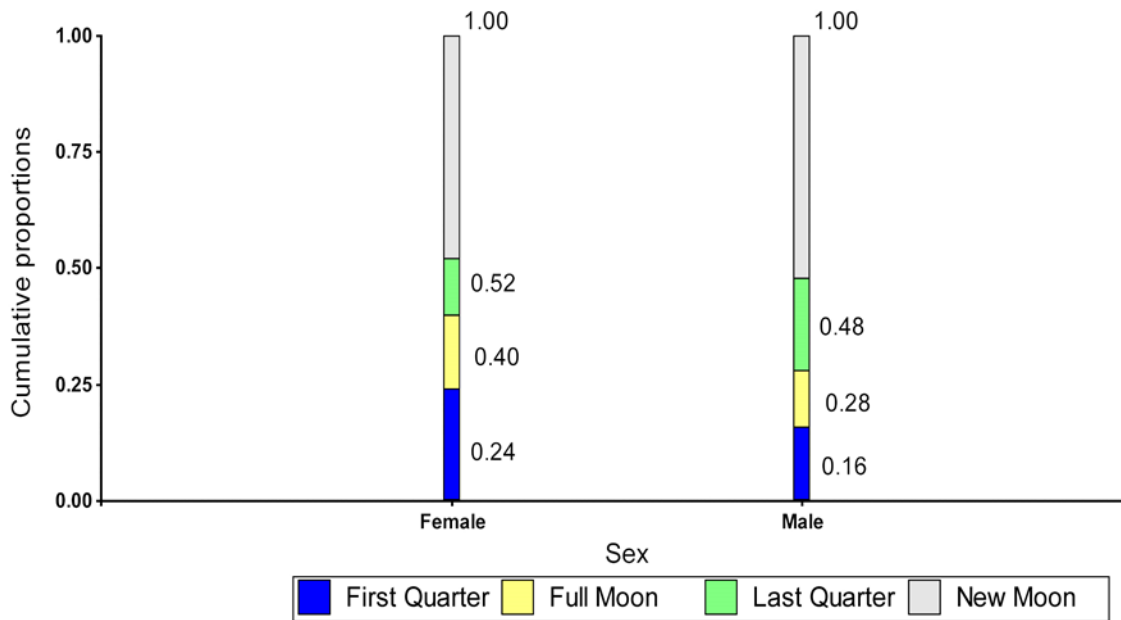


Figure 32. *Sphaerodactylus roosevelti* gender prevalence by lunar phases. No differences were found between male and female prevalence of species when compared with lunar phases (Chi-Square, p-value 0.6908).

In order to establish the presence of niche overlap between species and age categories, I include the following scatterplots with colored ellipses marking 95% confidence intervals. Figure 33 demonstrates slight overlap in percent of over story cover use (canopy cover) between species and age categories in all three temporal categories. Similarly, Figure 34 demonstrates overlap in substrate type use between species and age categories in all three temporal categories.

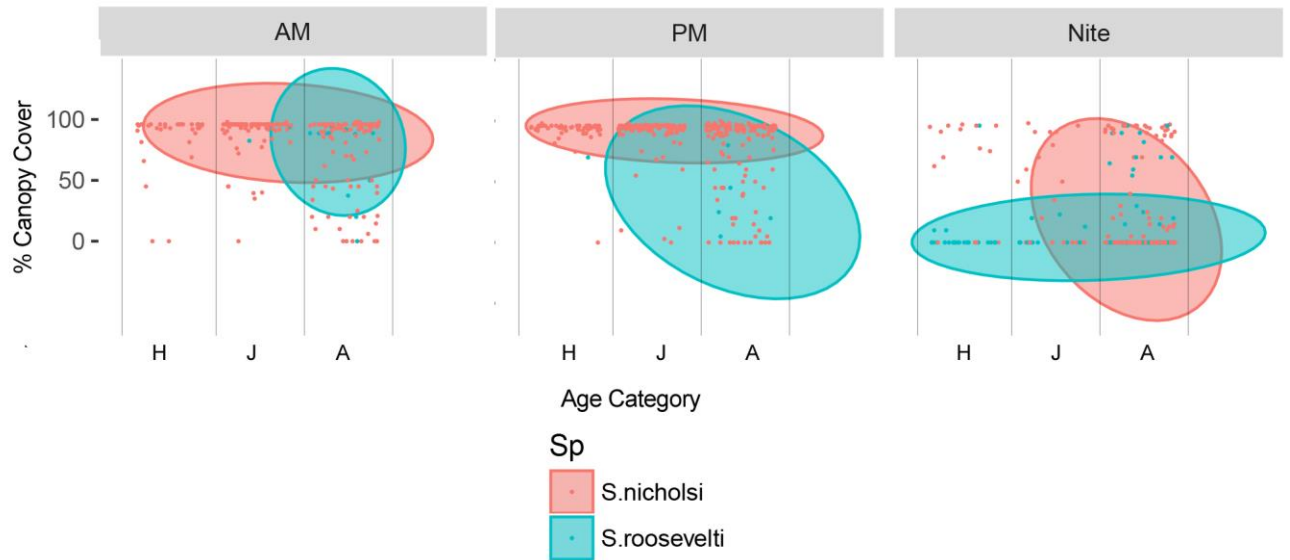


Figure 33. Niche Overlap in Over story cover (%) use between species and age categories. Interspecific and intraspecific overlap is seen in percent of over story cover use in all temporal categories.

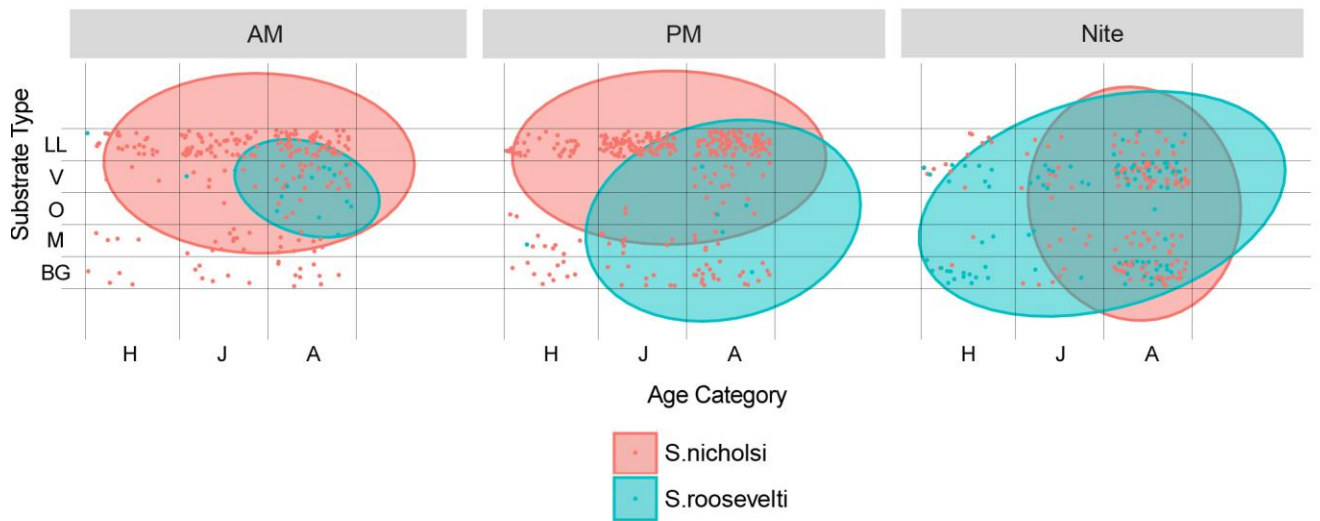


Figure 34. Niche Overlap in Substrate type use between species and age categories.

Interspecific and intraspecific overlap is seen in substrate type use in all temporal categories

Discussion

Interspecific Resource Partitioning Between *S. nicholsi* and *S. roosevelti*

Sphaerodactylus nicholsi and *S. roosevelti* differed in their selection of substrate type within The Salt Flats Refuge (Table and Figure 1). *Sphaerodactylus nicholsi* was commonly found within leaf litter patches while *S. roosevelti* favored vegetation use. Prior investigations have identified leaf litter as a primary substrate for *S. nicholsi* at USFWS Refuge in Cabo Rojo (López –Ortiz and Lewis 2004). In contrast, Rivero (1998) previously described *S. roosevelti* as being strongly associated to cacti and palm tree debris within littoral zones as well underneath rocks, trunks and dry Agave Plants in Guánica forest. However, this will be the first time interspecific microhabitat use is described for both species in The Salt Flats Refuge in Cabo Rojo.

The predominant use of leaf litter for *S. nicholsi* serves many roles that ultimately benefit the species' survival. Firstly, leaf litter can aid *S. nicholsi* in the acquisition of available prey or food items. Leaf litter contains a vast amount of invertebrates that sphaerodactylids have been evidenced to prey upon (Steinberg et.al. 2007). Prey items for *S. nicholsi* and *S. roosevelti* have never been documented. However, Steinberg et al. (2007) evaluated *Sphaerodactylus vincenti* stomach content on St. Vincent and reported that some of these invertebrates include various orders of insects, crustaceans (Isopods), arachnids (Aranae, Acari) and diminutive gastropods (snails). Similarly, Pianka and Huey (1978) evaluated stomach content for various species of desert geckos and also reported arachnids such as scorpions and spiders as well as several orders of insects such as termites, Hemipteran, Lepidoptera and Orthopteran, among others.

Second, the leaf litter serves as a convenient shroud of protection in which the species can safely hide from predators such as *Pholidoscelis (Ameiva) exsul* and *Anolis cristatellus* that have been documented to prey upon sphaerodactylids in Puerto Rico (López-Ortiz and Lewis 2002, 2004). In addition, Lewis (1989) reported *Pholidoscelis (Ameiva) exsul* preying on eggs of *Anolis* lizards found in leaf litter patches in Mayaguez. Interestingly, he also reported various orders of insects, snails, isopods and arachnids as being prey of *P. exsul*. These prey are the same as those reported to *S. vincenti*, thus leading us to believe there may be some overlap in prey items used between endemic sphaerodactylids and *P. exsul* (albeit with differences in size of prey) which can

lead to spatial overlap of both species during foraging. Both *A. cristatellus* and *P. exsul* predators are present at The Salt Flats Refuge and actively hunt on study sites where I captured *S. nicholsi*. In support of the importance of leaf litter as protection from predation, I must also make note to the species' dark brown and mottled scales that are camouflaged perfectly within the leaf litter environment.

Thirdly, the leaf litter environment is paramount in assisting *S. nicholsi* in the prevention of desiccation due to the extreme heat and sunlight present at The Salt Flats Refuge. *Sphaerodactylus* species are very sensitive to cutaneous desiccation due to their small size and high surface area to volume ratio they rely heavily on behavioral thermoregulation rather than physiological constraints to control body temperature fluctuations (Allen and Powell 2014; Johnson et al. 2013; Nava 2004, 2006). Since species of *Sphaerodactylus* do not possess any specialized physiological mechanisms to assist with heat stress, they must solely rely on their microhabitat selection to avoid high levels of EWL. Due to the high risk of desiccation, *Sphaerodactylus* frequently are restricted to relatively moist and mesic microhabitats (Steinberg et al. 2007). Steinberg et al. (op.cit.) noted a trend in microhabitat preference of shady, moist and deep leaf litter areas when studying *Sphaerodactylus vincenti* in the West Indies (St. Vincent). The team remarked that the only plots that were completely absent of *Sphaerodactylus* had no shade and were lacking deep leaf litter patches as well as low temperature areas. They go on to state that these microhabitat preferences most likely relate to the fact that *Sphaerodactylus* from areas with high moisture lose cutaneous water easier than xeric species. Furthermore, while studying *S. gaigae*, *S. macrolepis* and *S. townsendi*, Nava (2004) stated that humidity was the most vital parameter used for habitat selection.

In addition, Maclean and Holt (1979) have attributed water loss rates to strong parapatric distribution between interspecific *Sphaerodactylus* in St. Croix. The endemic *S. beattyi* was being excluded from mesic areas due to *S. macrolepis* introduction. Since both species are of similar size and behavior, strong competition was being evidenced by sharp defined distribution boundaries. Snyder (1975) had previously found that *S. macrolepis* and *S. beattyi* differed in their EWL rates. Between the two species, *S. macrolepis* had a larger evaporative water loss rate than did *S. beattyi* forcing *S. beattyi* to

inhabit drier microhabitats that *S. macrolepis* cannot use; thus minimizing competition and increasing chances of species survival in an otherwise grim scenario that often leads to the extinction of the least adaptable of the two competing species (Maclean and Holt 1979).

Most sphaerodactylids can be considered thigmotherms and thermoconformers, thus their use of selected substrates in microhabitat is important for their survival. It has been documented that leaf litter patches tend to provide cooler and lower temperatures than other substrates such as bare ground which are exposed to direct sunlight (López-Ortiz and Lewis, 2004). Without leaf litter patches to retreat to and assist in thermoregulation they could be at risk of overheating and or death. Similarly to López-Ortiz and Lewis' (2004) findings at the USFW refuge, some of the most common tree species that contribute to over-story cover and leaf litter on my study sites were *Prosopis* sp. (deciduous), *Pithecellobium unguis cati* (evergreen), *Ziziphus reticulata* (evergreen) in addition to the following three species of mangroves found at Salt Flats Refuge: *Avicennia germinans* (Black), *Conocarpus erectus* (Button) and *Laguncularia racemosa* (white) (Table 4)

By contrast, *S. roosevelti* was most commonly found on *Fimbristylis cymosa* vegetation (Table and Figure 3). *Fimbristylis cymosa* is a dense grass like plant that has a tendency to retain humidity, which is an important factor in *Sphaerodactylus* microhabitat selection (Nava 2004; 2006). *Sphaerodactylus roosevelti* may be using the plant as a safe hiding place to ward off predators and also as a mechanism to avoid desiccation much like *S. nicholsi* does with leaf litter.

In addition, during my investigation, I evidenced several individuals (females and hatchlings) of the species using *Fimbristylis cymosa* as substrate while eggs were present underneath plant. Therefore, I believe that female *S. roosevelti* use *Fimbristylis cymosa* as a communal nest site. Doody et.al (2009) discusses the presence of communal nesting across several species of reptiles and amphibians. Within the Gekkonidae family, they report that 129 of 1057 oviparous species nest communally (Doody et al. 2009). Reptilian communal nesting has been reported as occurring between conspecific and interspecific females (Alfonso et al. 2012; Krysko et al. 2003). In the Florida Keys, Krysko et al. (2003) reported evidence of interspecies communal oviposition for four

species within the Gekkonidae family. The investigation included evidence from two different nests found in soil and leaf litter at the base of the tree *Casuarina equisetifolia*. The species that occupied nests are as follows: Nest #1 contained two eggs from *Hemidactylus frenatus*, one egg from *H. mabouia* and three from *Sphaerodactylus elegans*. Nest #2 contained eight eggs with the following distribution: two eggs from *S. elegans*, four eggs from *S. notatus* and two eggs from *Hemidactylus mabouia* (Krysko et al. 2003). The investigators concluded that communal nesting might be a primitive trait within the Gekkonidae family used to ensure clutch success. In addition, Alfonso et al. (2012) noted communal oviposition in Cuba between two different families of lizards: Gekkonidae and Iguanidae. The nest was found within an Agave plant and included 8 intact, unhatched eggs. The results were as follows: three eggs belonged to *Sphaerodactylus armasi*, three eggs to *Tarentola combiei* and two eggs belonged to *Anolis* sp. Although the underlying reasons or causes for communal nesting are not fully understood yet, two main hypotheses are postulated. The “by-product” or scarcity of nest site hypothesis and the “adaptation” hypothesis, which includes some benefit toward the mother and / or hatchlings (Doody et al. 2009; Radder and Shine 2007). After studying the Australian skink *Bassiana duperreyi*, Radder and Shine (2007) concluded that the adaptive hypothesis was the most likely reason for communal nesting in reptiles because females in laboratory had a tendency to lay eggs in nests marked by cues from previous females without having a scarcity of other sites and hatchlings that were within communal incubation were faster and larger. Radder and Shine (2007) attribute the differences between the hatchlings to low hydric exchange between eggs incubated within communal nests. Although this evidence may support the fact that *S. roosevelti* uses conspecific or interspecific communal nesting, I cannot discard the possibility that the nest found underneath *Fimbristylis cymosa* might have harbored eggs belonging to same female. The lack of precise reproductive information on species limits my conclusions.

Although I suggest habitat differentiation between species, I have to consider the fact that these two *Sphaerodactylus* are not completely spatially isolated from each other. Both species use most types of substrate type only to a differing degree thus potentially limiting interspecific resource overlap at The Salt Flats Refuge. I must also note that

habitat partitioning parameters may be influenced by interspecific stressors (Frankenberg 1978; Huey and Pianka 1983). Similarly, *Hemidactylus turcicus* and *Tarentola mauritanica* in the Mediterranean display habitat variation depending on whether or not they are living in allopatry or sympatry. For example, *H. turcicus* living in allopatry usually prefers open habitat with vegetation cover, whereas in sympatry usually selects more closed habitats (Lisičić et al. 2012). By contrast, in sympatry the dominant *T. mauritanica* uses more open habitats (Lisičić et al. op. cit.).

Although leaf litter and vegetation were the main substrate types used by my study species, the importance of the use of fallen termite mounds in “other” substrate category for both species should be noted as it is mentioned by Rivero (1998) in terms of a possible food supply for *S. roosevelti* and Nava (2006) as substrate for various *Sphaerodactylus* sp. (Table 2 and Figure 2). Fallen termite mounds offer these diminutive geckos a place to seek refuge from inclement weather and predators while offering a chance to feed on live termites still found inside fallen mound.

In terms of over story cover percentage, *S. nicholsi* and *S. roosevelti* differed dramatically in the amount of canopy cover each species selected. *Sphaerodactylus nicholsi* selected the greatest amount of over story cover (Table 6 and Figure 5). Not being exposed to direct sunlight is crucial for sphaerodactylids due to the risk of cutaneous desiccation previously discussed. However, *S. roosevelti* avoids this risk by being more active during night time hours (after 6:45 p.m.), whereas *S. nicholsi* is most active in the afternoon (12:01-6:44 p.m.) (Table 7 and Figure 6). By preferring a nocturnal activity pattern, *S. roosevelti* can afford to have minimal over story canopy cover because, the species is at a reduced risk of overheating (i.e. desiccation).

Temporal partitioning may have many causes, some of the most common being to reduce risk of predation as well as competition on the spatial and dietary scale. Predator presence has a vast influence on lizard microhabitat selection as well as on behavioral modifications and overall fitness (Downes and Shine 1998; Downes 2001). For instance, Downes (2001) performed laboratory tests on the garden skink, *Lampropholis guichenoti* and compared resource acquisition and activity in presence and absence of snake predator scents. When exposed to snake predator scents, the skinks remained most of the time hidden in shelters, becoming active later in the day and minimizing movement rate which

negatively affected their basking and foraging patterns. In addition, the skinks that were reared with the presence of snake scents grew smaller, had slower sprint speed and produced smaller clutches during reproduction (Downes 2001). Similarly, while studying the Australian nocturnal gecko, *Oedura lesueurii*, otherwise referred to as the Velvet Gecko, Downes and Shine (1998) demonstrated the importance of microhabitat selection switching when undergoing predator avoidance. Geckos that were not exposed to snake scent preferred warm, sunny retreat sites perfect for body temperature regulation. However, when encountered with warm sites that had snake scent they chose the cold, shady retreat that although not thermally optimal, was considered to be the safer choice to ensure survival. Therefore, It was concluded that the species regards predator avoidance a higher priority than thermoregulation (Downes and Shine, op. cit.).

Detailed information on diet is unknown for *S. nicholsi* and *S. roosevelti* at The Salt Flats refuge so the influence of diet on possible resource partitioning between species remains undetermined. However, insights between interspecific *Ctenotus* skinks' diet, over space (3 sites) and time (5 censuses within 16 year span), were conducted by Goodyear and Pianka (2011) in Australia. Most relevant results concluded that great variation existed between species with *C. calurus* and *C. pantherinus* eating mostly termites, *C. quattuordecimlineatus* consuming bigger prey such as spiders and grasshoppers and *C. pianka* mostly using insects within the order Hemiptera as prey. Furthermore, diets of all species varied by site and time with limited overlap between species thus implying vital ecological differences between species (Goodyear and Pianka, 2011). In regards to *S. nicholsi* and *S. roosevelti* I have established they have ecological differences between them such as use of substrate type and temporal activity preferences aside from morphometrical variation. Therefore, it would be safe to infer that differences between species is likely to exist in terms of realized food niche (size and taxon) at The Salt Flats refuge. Interestingly, Schoener (1974) described the “food type dimension” of a niche as being of intermediate importance when compared to habitat and temporal dimensions between species. In lizards, spatial partitioning seems to be most prevalent (Toft 1985). However, I should be careful to consider the implications of *S. nicholsi* and *S. roosevelti* using temporal partitioning at the Salt Flats refuge. Most sympatric congeners have very similar ecological requirements and commonly have similar

physiological needs that are reflected in their habitat and dietary needs. For example, Kronfeld-Schor and Dayan (1999) postulated dietary overlap as the possible causes for temporal partitioning in two species of rodents within the genus *Acomys*. In this case, arthropods were reported as being a primary food choice for both species, it was suggested that by one species being diurnal and the other nocturnal each species may be exposed to different types of arthropods (species and taxon) since diel cycles in arthropods vary. Comparably, Huey and Pianka (1983) concluded that temporal differences between nocturnal and diurnal lizards with very similar diets were associated with reduced levels of dietary overlap. Similarly, Rouag et al. (2007) concluded that temporal partitioning was a mean to reduce interspecific strain on prey and microhabitat resources between two sympatric lizard species in Algeria. In these cases, two similar, closely related interspecific species may develop temporal partitioning as a means to reduce the event of prey overlap thus reducing competition. However, it is important to reiterate that resource partitioning (of any type) between species does not guarantee the initial presence of competition (cause and effect relationship) or ensure its elimination. Similarities between *Sphaerodactylus* species dietary preference may help explain causes for temporal partitioning at the Salts Flats Refuge. However, if interspecific differences in prey are confirmed then other factors should be considered as possible causes for temporal partitioning.

In order to fully understand the interspecific ecology of *S. nicholsi* and *S. roosevelti*, data on all three niche dimensions (Habitat, Food and Temporal) is vital since none of the variables function independently. For example, in the Seychelles Islands, two species of diurnal geckos (*Phelsuma* sp.) evidently partition their microhabitat by height of tree perch as well as tree species (habitat), are suggested to be more active at differing times of day (Temporal) and one species possibly prefers the use of pollen as primary diet (food) (Noble et al. 2011). Additionally, investigations should be made on individual populations of *S. nicholsi* and *S. roosevelti* in allometry to evaluate influence of interspecific competition on resource utilization.

Along with the evidence of *S. roosevelti* preferred nocturnal activity I also have strong evidence that suggests that the species exhibits Lunar Phobia, which is marked by reduced foraging activity during increased lunar illumination (Full moon) and inversely

increased foraging activity during less lunar illumination (New Moon) (Table 23 and Figure 14). It must be noted that no other environmental factors such as temperature, cloud cover, or rain were taken into account. It has been stated that moonlight influences foraging efficiency by increasing activity for predators and reducing activity for prey (Seligman et al. 2007; Werner et al. 2006). Nocturnal geckos are an interesting example for this principle because they are both a predator to arthropods and a prey to other vertebrates (birds, lizards and mammals). In effect, each species must act on the basis of “trade-off” between the risks of being detected by predators or the benefits of having better illumination to capture prey (Seligman et al. 2007). This concept may be quite relative since it may depend on habitat, seasons, scarcity of food, and or potential predators present. In addition, Seligman et al. (op.cit.) suggested that eye size of the nocturnal gecko may play a determinant role in species activity during moonlight. He suggested that since moonlight depressed activity in the relatively large *Teratoscincus scincus*, the species may be able to avoid foraging in illumination because its’ large eyes allow for better nocturnal vision and prey capture during darkness. Similarly, when comparing moon illumination to activity of male and female *Goniurosaurus kuroiwa* Werner et al. (2006) reported decreased activity during low illumination for the smaller male and increased activity during darkness for the larger female. I can infer since *S. roosevelti* is the largest species of *Sphaerodactylus* in Puerto Rico, its large eyes may supply sufficient nocturnal vision to be able to forage in darkness and avoid being seen by predators at The Salt Flats refuge. Interestingly, it is worth mentioning that this species has been documented to have the ability to climb as high as 5 feet in the canopy during the night at The Salt Flats refuge (Deborah and Brian Muñiz, Pers. Comm.).

Since desiccation is a big risk, temperature is a vital factor for all *Sphaerodactylus* sp. Most species within the genus *Sphaerodactylus* inhabit mesic habitats whereas *S. nicholsi* and *S. roosevelti* live in a xeric environment where temperatures can increase to over 37 degrees Celsius (100°F) during summer months. They avoid overheating by behavioral thermoregulation influenced by substrate and temporal activity selection. In other words, *Sphaerodactylus* prevent desiccation by choosing cooler patches with lower temperatures within their microhabitat (Leclaire 1978; Snyder 1979; Nava 2001; Steinberg 2007). Although my study species coexist in one habitat their threshold for temperature limits

varies, and these differences are most likely influenced by character displacement involving species size and physiology.

Differences in size is quite marked between species, since *S. nicholsi* is the smallest *Sphaerodactylus* on island and *S. roosevelti* is the largest (Rivero 2006). These differences in size will also most likely include differences in species physiological requirements such as their optimal temperature gradient, as well as evaporative water loss rates that will in turn influence species niche selection parameters such as type of substrate, time of activity or prey (Nava 2006; Pianka and Huey 1978; Snyder 1975, 1979; Vanhooydonck et al. 2000). Prior studies on other species of *Sphaerodactylus* have demonstrated that the ratio of cutaneous evaporative water loss increases as size decreases (Bentley 1976; Johnson et al. 2013; Turk et al. 2010). Due to their small size, sphaerodactylid geckos are very susceptible to cutaneous desiccation, otherwise termed Evaporative Water loss or EWL (Leclair 1978; Snyder 1979; Nava et al 2001; Steinberg et al. 2007). Snyder (1975) noted that 94% of total water loss in *Sphaerodactylus macrolepis* was cutaneous. Johnson et al. (2013) found that gecko size does indeed have a significant effect on evaporative water loss rates. A larger species, *Hemidactylus mabouia*, had a lower cutaneous EWL ratio than smaller species, *Sphaerodactylus notatus*, due to lower surface area to volume ratios. Similarly, Bentley (1976) and Turk et al. (2010) noted that smaller animals lost water faster than larger individuals and this may be due to the relationship of body size to biomass. Thus, larger lizards have relatively less surface area from which water is lost than smaller ones.

Likewise, López-Ortiz and Lewis (2002) observed that the hatchlings within the genus are the most sensitive to cutaneous water loss due to their miniscule size (SVL-8-12mm). Although *S. nicholsi* is documented as reproducing all year long, it has been suggested that the species exhibits seasonal reproduction cycles that increase reproductive activity during the summer (egg incubation) and produce hatchling emergence in the fall-winter months (López-Ortiz and Lewis op. cit.). They suggested that “timed” reproduction with the goal of producing hatchlings during colder months and shorter days was essential to ensure survival.

Based on this, I can infer that *S. nicholsi* would in theory be more susceptible to desiccation than *S. roosevelti*, which would explain the higher temperature mean of *S. roosevelti* versus *S. nicholsi* evidenced in this study (Figure 12). Further studies involving optimal thermal niche components should be conducted in order to further analyze possible resource use of each species within a given habitat and be able to predict climate threats and conservation strategies.

Related to size between species, I conducted linear regressions to evaluate possible relationships between SVL (mm) and Weight (g) with the aim to elucidate new data on body condition index (BCI) of NON-Gravid adults of each species. Based on results of Jakob et al. (1996), I used the ratio index formula because of the low amount of variation of body sizes within populations of *S. nicholsi* and *S. roosevelti* and arrived at similar results for each species. For *S. nicholsi*, only 13% of population data can be explained as having a linear relationship between SVL (mm) and Weight (g) (Table 9 and Figure 8). For *S. roosevelti* only 11% of population data can be accounted as having linear relationship between SVL(mm) and weight(g) (Table 8 and Figure 7), Interestingly, both species body condition Index can be explained as follows: For every 1mm in SVL that the animal increases, 0.02g of weight will be increased as well. It may seem that the regression accounts for a very small amount of the overall population but certain limitations have to be considered. For instance, the weight (g) for each individual was measured using a Pesola scale and not a digital scale so weights were not completely continuous in nature. This means that many individuals had overlap in their weights thus possibly negatively affecting results. On the other hand, no information is currently available regarding body condition indices of either study species so having evidence that accounts for some data (albeit low accountability) may still be invaluable to ecological studies. The purpose of the Body Condition Index is to evaluate the “fitness” of a species within a population but it is not perfect and may have limitations. Dudek et al. (2014) shed light on this issue by evaluating the use of Body condition Index on fitness of *Lacerta agilis* (Sand Lizards) in Poland. The team concluded that the index is unreliable because in the case of his study species, the lizard’s body length (SVL) increased at a quicker speed, regardless of age whereas mass increased later during lizard’s development. Since these two parameters do not increase at the same rate of development

they cannot be considered to have a linear relationship (Dudek et al. 2014). However, by taking into account this limitation I only included adults (Non Gravid) in my evaluation of BCI for *S. nicholsi* and *S. roosevelti* in an attempt to modify any skewed results brought on by differences in age categories. Furthermore, weight may also be a fickle parameter to rely on to measure BCI in lizards because it can be influenced by many extraneous factors such as tail autotomy and whether or not specimen has digested and defecated recently i.e.: size and date of last meal (Meiri 2010). Moreover, Meiri (2010) concluded that the shape of species and presence and absence of limbs is as vital for predicting lizard mass as SVL. Likewise, it is suggested that ecological factors such as feeding and movement are key because of differences required for success in different habitats (op.cit.) For example climbing, or arboreal lizards will be lighter than terrestrial ones and species that use “sit and wait” instead of “active foraging” will have a tendency to be heavier (op. cit).

Since I evaluated “fitness” parameters for non-gravid adults of each species using the BCI linear regression, I also wanted to compare reproductive patterns of each species by seeing how many gravid females were present during each season of the year. My results were consistent with the literature that states that vertebrates were less likely to partition by seasonal reproduction than invertebrates (Schoener 1974). Gravid females of each species were found throughout year but there was an increase of gravid females on winter and summer for *S. nicholsi* while *S. roosevelti* had an increase during summer and fall (Figure 13).

Since abundant reproduction information is lacking for both species, I compared *S. nicholsi* Salt Flats data with results by López-Ortiz and Lewis (2002), who also conducted their research in Cabo Rojo (USFWS Refuge) from summer 1997-1998. Similarly to López-Ortiz and Lewis (op. cit.), gravid females were abundant in summer months but more prevalent during winter at Salt Flats refuge, where they were absent during the month of January in the previous study. Rainfall has previously been established as a factor that influences reproduction in many tropical lizard species (Colli 1991; Heatwole and Taylor 1987; Licht and Gorman 1970; Gorman and Licht 1974; Sexton et al. 1963; Stamps 1976). López and Lewis (2002) stated that no correlation was found between gravid females and rainfall during their study but they did mention that

the amount of rainfall for their study year (summer 1997-1998) was uncharacteristically low when compared to the 17 years average used during their research. Based on this information, I reviewed the monthly rainfall for the years 1997, 1998, 2016 and 2017 at USFWS Cabo Rojo refuge (data was supplied by James Padilla of USFWS). I noted that the total amount of rainfall for January 1998 was 2.06 cm whereas the average during my study was 3.05 cm. The increase in rainfall of January 2016 and January 2017 during my research may account for the high abundance of gravid females during winter season. Increased rainfall would trigger high humidity levels which are vital for *Sphaerodactylus* found in Puerto Rico (Nava 2004; 2006) and may in turn bring increased food supply in the form of insects and other arthropods which may influence sphaerodactylid reproductive patterns. In turn, López-Ortiz and Lewis (2002) argued that by having an increase of abundance of gravid females during summer months, the species is safeguarding the survival of offspring by exposing hatchlings to months with lower heat stress. I agree with this statement because since my results dictate that the majority of gravid females were found in summer and winter, those clutches in question would hatch during spring or fall. Ultimately, different populations of conspecifics will ultimately have different environmental cues that influence reproductive cycles such as food availability, amount of humidity, temperature and predation among others (Heatwole and Taylor, 1987; Stamps 1976). Aside from these extraneous factors I must also take into account the presence of fat and glycogen deposits that influence reproductive cycles of reptiles (Heatwole and Taylor 1987; Licht and Gorman 1970; Gorman and Licht 1974). For example, if food or water were limited, due to possible droughts brought on by global warming then a way to compensate would be to reduce body size in order to reduce resource requirements. Furthermore, Bickford et al. (2010) and Clusella et al. (2011) noted the importance of precipitation as a factor determining fitness by means of preferred temperature for thermoregulation, growth rates, development and reproduction among ectotherms.

Previous studies have discussed the differences of microhabitat use in *Sphaerodactylus* species found in allopatry and those found in sympatry within the island of Puerto Rico (Nava 2004). It is imperative to reiterate that results from my investigation are limited to data found where *S. nicholsi* and *S. roosevelti* coexist in sympatry. Further

studies regarding *S. roosevelti* and *S. nicholsi* ecology in sites without the presence of any other sphaerodactylids are needed to arrive at precise ecological selection parameters of this species that may serve to support future conservation efforts.

Intraspecific Resource Partitioning Between Age and Gender categories

As expected, I found that substrate type, overstory cover percent, seasonal prevalence, and morphometrical measurements differ significantly between age categories of each species. Furthermore, in *S. nicholsi* intraspecific temporal differences were also present between age categories (Table 15 and Figure 19). It is important to reiterate that for each species, the larger adults chose the more hidden substrate, secure from predators and environmental risks. This could potentially be caused by the fact that the adults are the more dominant age category due to larger size when compared to juvenile and hatchlings. The younger and smaller, in turn more vulnerable conspecifics may simply avoid adult competition by selecting different substrates than adults. Similarly, when studying intraspecific differences of habitat use of *Hemidactylus turcicus* and *Tarentola mauritanica*, Lisičić et al. (2012) found that juvenile geckos selected relatively open habitats when compared to adult conspecifics and rarely entered areas containing adult conspecifics. Interestingly, Lisičić et al. (op. cit.) also noted that age classes of *H. turcicus* differed in habitat use when found in allopatry versus sympatry with the more dominant *T. mauritanica*. Whether or not intraspecific age category substrate type use is influenced by interspecific constraints cannot be determined without data of each species in allopatry. However, I can infer that it is a possibility at The Salt Flats Refuge.

Along with differences in substrate type, intraspecific variation in over-story percent by age category was also evidenced. The significant differences seen for over-story cover percent may in fact be influenced by the differences in age category size and physiological differences such as evaporative water loss. It would be vital for the diminutive hatchlings and juveniles to safeguard against desiccation by finding highly shaded patches within their microhabitat that prevent direct sunlight. Since the adults are significantly larger, they may have a lower EWL rate than the younger age categories and

thus can withstand increased influence of sunlight. In contrast, *S. roosevelti* displays a more direct linear relationship with age category and over-story cover percent. Therefore, the risks of cutaneous desiccation due to heat stressors such as direct sunlight are reduced in *S. roosevelti*. However, increased over-story cover during nocturnal activity patterns does protect the species from being detected by predators from direct moonlight thus supporting my evidence of lunar phobic foraging patterns for *S. roosevelti*. Smaller individuals such as juveniles and hatchlings can be more effectively hidden due to miniscule size, in turn may not need to have such high over story cover to shield themselves from inherent dangers present.

Seasonal prevalence varied significantly between age categories of each species at The Salt Flats refuge (Tables 20 and 21, Figures 20 and 26). For *S. nicholsi* adults had an increased prevalence during summer and winter months when temperatures are the most extreme and rainfall is usually the lowest (based on data from 1980-2017; provided by James Padilla, USFWS). In contrast, juveniles and hatchlings were most prevalent during the fall where rainfall has a tendency to be increased (based on data from 1980-2017; provided by James Padilla, USFWS) and temperatures are more suitable for diminutive individuals to avoid desiccation and overheating. Similarly to López-Ortiz and Lewis (2002), hatchlings were less prevalent during summer months at the Salt Flats, which may further support the negative role of high temperatures and low rainfall on presence of this age category. My data on adults being more prevalent during summer and winter is positively correlated with the prevalence of gravid females during these epochs. For *S. roosevelti*, prior studies to compare age category seasonal prevalence are lacking. At The Salt Flats, adults and juveniles of *S. roosevelti* were more prevalent during the fall whereas hatchlings were more commonly found during the spring (Table 21 and figure 26). Since *S. roosevelti* is the more nocturnal species in sympatry with *S. nicholsi* it may be possible that age category prevalence may be associated to more factors than just temperature and humidity. Perhaps, prey availability, predator presence and lunar influence may be variables to consider. More studies are necessary in order to establish accurate seasonal age category prevalence for the species.

For intraspecific comparisons between male and female *S. roosevelti*, only tail length had significant differences (Table 22 and Figure 29A). The benefits of males having a

longer tail may be based on dominance and territoriality, increased predation risk and or gender morphometric differences. For instance, Barbadillo (1997) tested the hypothesis that male lizards had a longer total tail length due to the effect of the hemipenes on the tail base. He concluded that the hemipenes do in fact create a longer “non- autonomous tail base” that cannot break away at the sign of danger but reported that he could not find significant correlation between total tail length dimorphism in lizards (op. cit.). However, the effect of presence of hemipenes on longer tail length has been confirmed in male snakes (King 1989). In terms of aggression and dominance, Regalado (2003) described tail thrashing as a behavior used by both sexes of *S. nicholsi*. Regalado (2003) and Allen et al. (2015) reported that aggression occurred in both sexes of various species of *Sphaerodactylus* during same sex interactions as well as between male and females. Regalado (2003) reported that tail thrashing occurred between males to establish dominance and also between male and females when the female was rejecting the males’ copulatory advances. Furthermore, Allen et al. (2015) reported that within *S. notatus*, larger males were more successful in defending shelters from other males.

However, it was stated that tail loss did not have a great influence on outcomes of dominant interactions within the study population. Similarly, Medel et al. (1988) argued that the amount of tail autotomy present in a population cannot be an accurate direct measure of predation on that population but rather it should be considered a measure of the failed attempt of predation. He reported that tail autotomy was only successful against predation by certain species such as snakes and Teiids but inefficient for predators such as falcons (op. cit.). Furthermore, he argued that the hunting mechanism of each predator ultimately determined success or failure of prey capture and tail autotomy escape patterns (op. cit.). Moreover, Werner et al. (2006) concluded that tail loss increased the activity of females but reduced activity within males of *Goniurosaurus kuroiwae*. I could then consider that male *S. roosevelti* with marked tail loss were less likely to be captured due to decreased activity. It is possible that since males of the species have a slightly larger snout vent length (SVL) although not statistically significant, this may in turn influence their development of a larger tail than the females. Since prior studies on this topic are absent in literature for *S. roosevelti*, I can only speculate as to the ecological significance

of males having longer tails than females within the population on *S. roosevelti* at The Salt Flats.

Ultimately, when evaluating intraspecific resource comparisons, the size of the animal will most likely be closely related to differing physiological requirements that will guide their ecological selection parameters such as habitat, prey and preferred time of activity.

For example, Polis (1984) evaluated the role of desert scorpion (*Paruroctonus mesanesis*) age categories on prey differences and attempted to confirm whether or not to consider these age categories as separate “ecological species”. He concluded that for *P. mesaensis* variations between preys selected by different age groups could rival differences found in interspecific competition scenarios. However, he postulated that age groups within conspecifics are influenced to diverge in resource use where there is an absence of interspecific competition present. Thus, It must be reiterated that studies of each age category in allopatry must be conducted in order to arrive at accurate conclusions of intraspecific resource partitioning for *S. nicholsi* and *S. roosevelti* age categories.

Conclusions

I described microhabitat selection for *S. nicholsi* and *S. roosevelti*. I concluded that *S. nicholsi* could commonly be found in leaf litter in contrast to *S. roosevelti*, which prefers vegetation, the most prevalent being *Fimbristylis cymosa* and *Batis maritima*. In addition, I established that *S. nicholsi* selects for more shady areas within habitat, with a significantly higher mean of over-story cover percent when compared to *S. roosevelti*. However, no statistical differences were found between species within the “other” substrate type category, with both species predominantly being found inside termite mounds. Similarly, no statistical differences were seen in Leaf litter depth (cm) use between species. The differences in substrate and over-story use between species support my hypothesis that these species differ in microhabitat selection parameters within The Salt Flats refuge.

Moreover, I identified that *S. nicholsi* was more active during the afternoon (PM), while *S. roosevelti* showed a nocturnal activity pattern. I also have evidence to suggest that *S. roosevelti* exhibits Lunar Phobia, thus being less active during full moon where moon has maximum illumination. The differences in temporal activity patterns between species support my hypothesis that these species differ in their temporal activity patterns at The Salt Flats refuge.

Furthermore, I conclude that *S. nicholsi* and *S. roosevelti* partition their resources by means of temporal and spatial means in order to co-exist at The Salt Flats refuge thus supporting my hypothesis. However, I cannot precisely state that underlying reasons such as competition are the driving factor behind this strategy.

Similarly, intraspecific differences between age categories are present in both species for substrate type and over-story percent use, seasonal prevalence and temporal activity patterns (*S. nicholsi* only). These differences suggest that both interspecific and intraspecific resource partitioning occurs at The Salt Flats Refuge thus supporting my hypothesis. However, the role of physiology in determining resource partitioning between age categories and species still remain unknown.

Future Recommendations

1. Physiological tests such as Evaporative Water Loss (EWL) rates should be conducted for each species in order to discern the influence of physiological and temperature tolerance requirements on each species resource selection parameters.
2. Ecological studies on each species in allopatry should be conducted in order to evaluate possible influence of competition on interspecific microhabitat selection.
3. Further studies should be performed testing lunar influence on *S. roosevelti* taking into account other environmental factors such as cloud cover, rain, presence and identification of possible nocturnal predators (i.e., birds, mammals, etc.).
4. Further studies should be evaluated regarding each species optimal thermal niche and preferred humidity levels.
5. Research should be carried out on stomach contents by means of dissection or stable isotopes to discern prey animals of *S. nicholsi* and *S. roosevelti* at The Salt Flats Refuge, in order to have data on all three types of known resource partitioning (Spatial, Temporal and Food). This data along with data in allopatry and thermal niche could be vital in future conservation efforts of species and may help assist in deciphering causes of partitioning at The Salt Flats Refuge.

Literature Cited

- Alfonso, Y.U., Charruau, P., Fajardo, G. and Estrada, A.R. 2012. Interspecific communal oviposition and reproduction of three lizard species in Southeastern Cuba. *Herpetology notes* **5**:73-77.
- Allen, K.E. and Powell, R. 2014. Thermal biology and microhabitat use in Puerto Rican eyespot geckos (*Sphaerodactylus Macrolepis Macrolepis*). *Herpetological Conservation and Biology* **9**(3):590-600.
- Allen, K.E., Avilés Rodríguez, K.J., Eifler, D.A. and Powell, R. 2015. Social and environmental factors influence microhabitat selection in the Brown- Speckled Sphaero, *Sphaerodactylus notatus* (Squamata: Sphaerodactylidae). *Journal of Herpetology* **49**(2): 165-169.
- Alley, T.R. 1982. Competition theory, evolution and the concept of an ecological niche. *Acta Biotheoretica* **31**:165-179.
- Álvarez, H.J. 1992. Thermal characteristics of *Sphaerodactylus* species in Puerto Rico and their implications for the distribution of species in Puerto Rico. Ph.D. Dissertation. University of Puerto Rico, San Juan, PR.
- Barbadillo, L.J. 1997. Sexual dimorphism of tail length in lacertid lizards: test of a morphological constant hypothesis. *Journal of Zoology; London* **242**:473-482.
- Bauer, A.M., Russell, A.P., and Shadwick, R.E. 1992. Skin mechanics and morphology in *Sphaerodactylus roosevelti* (reptilian: Gekkonidae). *Herpetologica* **48**(1):124-133.
- Bentley, P.J. 1976. Osmoregulation. In Gans, C., and Dawson, W.R. (eds.), *Biology of the Reptilia*. W1.5. Physiology **A**:365-412.
- Bentz, E.J., Rivera Rodríguez, M.J., John, R.R., Henderson, R.W., and Powell, R. 2011. Population densities, activity, microhabitats, and thermal biology of a unique crevice- and litter dwelling assemblage of reptiles on union island, St. Vincent and the Grenadines. *Herpetological Conservation and Biology* **6**(1):40-50.
- Bickford, D., Howard, S.D., Ng, D.J.J and Sheridan, J.A. 2010. Impacts of climate change on the amphibians and reptiles of Southwest Asia. *Biodiversity Conservation* **19**:1043-1062.
- Clusella- Trullas, S., Blackburn, T.M. and Chown, S.L. 2011. Climatic predictors of temperature performance curve parameters in ectotherms imply complex responses to climate change. *The American Naturalist* **177**(6):738-751.

- Colli, G.R. 1991. Reproductive ecology of *Ameiva ameiva* (Sauria: Teiidae) in the Cerrado of Central Brazil. *Copeia* **(4)**:1002-1012.
- Daza, J.D., Abdala, V., Thomas, R., and Bauer, A.M. 2008. Skull anatomy of the miniaturized gecko *Sphaerodactylus roosevelti* (Squamata: Gekkota). *Journal of Morphology* **269**:1340-1364.
- Díaz-Lameiro, A., Oleksyk, T.K., Bird-Picó, F.J., and Martínez-Cruzado, J.C. 2013. Colonization of islands in the Mona passage by endemic dwarf geckoes (genus *Sphaerodactylus*) reconstructed with mitochondrial phylogeny. *Ecology and Evolution Open Access* **3(13)**: 4488-4500.
- Doody, J.S., Freedberg, S., Keogh, J.S. 2009. Communal egg-laying reptiles and amphibians: evolutionary patterns and hypotheses. *The Quarterly Review of Biology* **84**:229-252.
- Downes, S. 2001. Trading heat and food for safety: costs of predator avoidance in a lizard. *Ecology* **82(10)**:2870-2881.
- Downes, S., and Shine, R. 1998. Heat, safety or solitude? Using habitat selection experiments to identify a lizard's priorities. *Animal Behavior* **55**:1387-1396.
- Dudek, K., Sajkowska, Z., Gawalek, M. and Ekner-Grzyb, A. 2014. Using body condition index can be unreliable indicator of fitness: a case of sand lizard *Lacerta agilis* Linnaeus, 1758 (Sauria: Lacertidae). *Turkish Journal of Zoology* **38**:1-3.
- Frankenberg, E. 1978. Interspecific and seasonal variation of daily activity times of gekkonid lizards (Reptilia, Lacertilia). *Journal of Herpetology* **12**:505-519.
- Gamble, T., Greenbaum, E., Jackman, T.R., and Bauer, A.M. 2015. Into the light: diurnality has evolved multiple times in geckos. *Biological Journal of the Linnean Society* pages:1-15
- Gause, G.F. 1934. Experimental analysis of Vito Volterra's mathematical theory of the struggle for existence. *Science* **79(2036)**:16-17.
- Genet, K.S., Genet, J.A., Burton, T.M., and Murphy, P.G. 2001. The lizard community of a subtropical dry forest: Guánica forest, Puerto Rico. *Tropical Ecology* **42(1)**: 97-109.
- Goodyear, S.E., and Pianka, E. 2011. Spatial and temporal variation in diets of sympatric lizards (genus *Ctenotus*) in the Great Victoria Desert, Western Australia. *Journal of Herpetology* **45(3)**:265-271.
- Gorman, G.C., and Licht, P. 1974. Seasonality in Ovarian Cycles among tropical *Anolis* lizards. *Ecology* **55(2)**:360-369.

- Gunderson, A.R. and Leal, M. 2012. Geographic variation in vulnerability to climate warming in a tropical Caribbean lizard. *Functional Ecology* **26**:783-793.
- Harmon, L.J., Harmon, L.L., and Jones, C.G. 2007. Competition and community structure in diurnal arboreal geckos (genus *Phelsuma*) in the Indian Ocean. *Oikos* **116**:1863-1878.
- Heatwole, H., and Taylor, J. 1987. *Ecology of Reptiles*. Surrey Beatty and Sons PTY Limited, Australia.
- Hedges, S.B., and Thomas, R. 2001. At the lower size limit in amniote vertebrates: a new diminutive lizard from the West Indies. *Caribbean Journal of Science* **37(3-4)**:168-173.
- Hirzel, A.H., and Le Lay, G. 2008. Habitat suitability modeling and niche theory. *Journal of Applied Ecology* **45**:1372-1381.
- Huey, R.B. and Pianka, E.R. 1983. Temporal separation of activity and interspecific dietary overlap. In: Huey R.B., Pianka, E.R. and Schoener, T.W. (Eds.) *Lizard Ecology*. Harvard University Press, Cambridge **Ch. 13**:281-296.
- Huey, R.B., Deutsch, C.A., Tewksbury, J.J., Vitt, L.J., Hertz, P.E., Álvarez-Pérez, H.J., and Garland, T. 2009. Why tropical forest lizards are vulnerable to climate warming. *Proceedings of the Royal Society of London B: Biological Sciences*, rspb-2008.
- Hut, R.A., Kronfeld-Schor, N., Van der Vinne, V., and De la Iglesia, H. 2012. In search of a temporal niche: environmental factors. In A. Kalsbeek, M. Merrow, T. Roenneberg and R.G Foster (Eds) *Progress in Brain Research* pp. 281-304 Vol. **(199) Chapter 17**.
- Jaeger, R.G. 1970. Potential extinction through competition between two species of terrestrial salamanders. *Evolution* **24**:632-642.
- Jakob, E.M., Marshall, S.D., and Uetz, G.W. 1996. Estimating fitness: a comparison of body condition indices. *Oikos* **77(1)**:61-67.
- Johnson, S.K., Parmelee, J.S., Eifler, D.A., and Powell, R. 2013. Comparative water-loss rates of *Hemidactylus mabouia* and *Sphaerodactylus notatus* on Eleuthera Island, Commonwealth of the Bahamas. *Herpetology Notes* **6**:471-475.
- King, R.B. 1989. Sexual dimorphism in snake tail length: sexual selection, natural selection or morphological constraint? *Biological Journal of the Linnean Society* **38**:133-154.
- Kronfeld-Schor, N. and Dayan, T. 1999. The dietary basis for temporal partitioning food habits of coexisting *Acomys* species. *Oecologia* **121**:123-128.

Krysko, K.L., Sheehy III, C.M. and Hooper, A.N. 2003. Interspecific communal oviposition and reproduction of four species of lizards (Sauria: Gekkonidae) in the lower Florida Keys. *Amphibia-Reptilia* **24**:390-396.

Leclair, R. 1978. Water loss and microhabitats in three sympatric species of lizards (Reptilia, Lacertilia) from Martinique, West Indies. *Journal of Herpetology* **12**(2): 177-182.

Lewis, A. 1989. Diet Selection and Depression of Prey Abundance by an Intensively Foraging Lizard. *Journal of Herpetology*, **23**(2), 164-170. doi:10.2307/1564023

Licht, P., and Gorman, G.C. 1970. Reproductive and fat cycles in Caribbean *Anolis* lizards. University of California Publ. in Zoology 95:1-52.

Lisičić, D., Drakulić, S., Herrel, A., Đikić, D., Benković, V., and Tadić, Z. 2012. Effect of competition on habitat utilization in two temperate climate gecko species. *Ecological research* 27(3):551-560.

López-Ortiz, R., and Lewis, A. 2002. Seasonal abundance of hatchlings and gravid females of *Sphaerodactylus nicholsi* in Cabo Rojo, Puerto Rico. *Journal of Herpetology* **36**(2):276-280.

López-Ortiz, R., and Lewis, A. 2004. Habitat selection by *Sphaerodactylus nicholsi* (Squamata: Gekkonidae) in Cabo Rojo, Puerto Rico. *Herpetologica* **60**(4):438-444.

Maclean, W.P., and Holt, R.D. 1979. Distributional patterns in St. Croix *Sphaerodactylus* Lizards: the taxon cycle in action. *Biotropica* **11**(3):189-195.

Medel, R.G., Jiménez, J.E., Fox, S.F. and Jaksic, F.M. 1988. Experimental evidence that high population frequencies of lizard tail autotomy indicate inefficient predation. *Oikos* **53**:321-324.

Meiri, S. 2010. Length- weight allometries in lizards. *Journal of Zoology* **281**:218-226.

Murphy, R.W., McCollum, F.C., Gorman, G.C., and Thomas, R. 1984. Genetics of hybridizing populations of Puerto Rican *Sphaerodactylus*. *Journal of Herpetology* 18(2):93-105.

Nava, S.S. 2004. Microhabitat selection, resource partitioning, and evaporative water loss by dwarf geckos, (*Sphaerodactylus*), on Puerto Rico. Master of Science thesis. University of Texas at El Paso.

Nava, S.S. 2006. Size does matter. *Iguana* **13**(1):17-21.

- Nava, S.S., Lindsay, C.R., Henderson, R.W., and Powell, R. 2001. Microhabitat, activity, and density of a dwarf gecko (*Sphaerodactylus parvus*) on Anguilla, West Indies. *Amphibia-Reptilia* **22**:455-464.
- Noble, T., Bunbury, N., Kaiser-Bunbury, C.N., and Bell, D.J. 2011. Ecology and co-existence of two endemic day gecko (*Phelsuma*) species in Seychelles native palm forest. *Journal of Zoology* **283**:73-80.
- Petren, K., and Case, T.J. 1998. Habitat structure determines competition intensity and invasion success in gecko lizards. *Proc. Natl. Acad. Sci. USA –Ecology* **95**: 11739-11744.
- Pianka, E.R., and Huey, R.B. 1978. Comparative ecology, resource utilization and niche segregation among gekkonid lizards in the Southern Kalahari. *Copeia* (**4**):691-701.
- Pironon, S., Villellas, J., Thuiller, W., Eckhart, V.M., Geber, M.A., Moeller, D.A. and García, M.B. 2017. The Hutchinson niche as an assemblage of demographic niches: implications for species geographic ranges. *Ecography* **40**:001-010.
- Polis, G. 1984. Age Structure Component of Niche Width and Intraspecific Resource Partitioning: Can Age Groups Function as Ecological Species? *The American Naturalist*, **123**(4), 541-564. Retrieved from <http://www.jstor.org/stable/2460997>
- Powell, R., and Henderson, R.W. 1999. Addenda to the checklist of West Indian amphibians and reptiles. *Herpetological Review* **30**:137-139.
- Radder, R.S., and Shine, R. 2007. Why do female lizards lay their eggs in communal nests? *Journal of Animal Ecology* **76**:881-887.
- Regalado, R. 2003. Social behavior recognition in the Puerto Rican dwarf gecko *Sphaerodactylus nicholsi*. *Caribbean Journal of Science* **39**(1):77-93.
- Rios-Franceshi, A., Garcia-Cancel, J.G., Bird Pico, J.F. and Carrasquillo, L.D. 2016. Spatiotemporal Changes of the Herpetofaunal Community in Mount Resaca and Luis Peña Cay, Culebra National Wildlife Refuge, Culebra, Puerto Rico. *Life the Excitement of Biology* **3**(4):254-289.
- Rivero, J.A. 1998. Los anfibios y reptiles de Puerto Rico. Universidad de Puerto Rico: Editorial Universitaria, San Juan, Puerto Rico.
- Rivero, J.A. 2006. Guía para la identificación de lagartos y culebras de Puerto Rico. La Editorial Universidad de Puerto Rico. **1era edición**:43-59.
- Rouag, R., Djilali, H., Gueraiche, H. and Luiselli, L. 2007. Resource partitioning patterns between two sympatric lizard species from Algeria. *Journal of Arid Environments* **69**:158-168.

Roughgarden, J. 1976. Resource partitioning among competing species—a coevolutionary approach. *Theoretical population biology* **9(3)**: 388-424.

Schoener, T.W. 1974. Resource partitioning in ecological communities. *Science* **185(4145)**: 27-39.

Schwartz, A., and Henderson, R.W. 1991. *Amphibians and Reptiles of the West Indies: Descriptions, Distributions and Natural History*. Gainesville, Florida, Univ. of Florida Press.

Seligman, H., Anderson, S.C., Autumn, K., Bouskila, A., Saf, R., Tuniyev, B.S., and Werner, Y.L. 2007. Analysis of the locomotor activity of a nocturnal desert lizard (Reptilia: Gekkonidae: *Teratoscincus scincus*) under varying moonlight. *Zoology* **110**:104-117.

Sexton, O., Heatwole, H., and Meseth, E. 1963. Seasonal Population Changes in the Lizard, *Anolis Limifrons*, in Panama. *The American Midland Naturalist*, 69(2), 482-491. doi:10.2307/2422924

Sheridan, J. and Bickford, D. 2011. Shrinking body size as an ecological response to climate change. *Nature Climate Change* **1**:401-406.

Snyder, G.K. 1975. Respiratory metabolism and evaporative water loss in a small tropical lizard. *Journal of Comparative Physiology* **104**:13-18.

Snyder, G.K. 1979. Water loss and oxygen consumption in tropical *Sphaerodactylus*. *Oecologia* **38**:107–110.

Stamps, J.A. 1976. Egg retention, rainfall and egg laying in a tropical lizard, *Anolis aeneus*. *Copeia* **(4)**:759-764.

Steinberg, D.S., Powell, S.D., Powell, R., Parmerlee, J.S., and Henderson, R.W. 2007. Population densities, water-loss rates, and diets of *Sphaerodactylus vincenti* on St. Vincent, West Indies. *Journal of Herpetology* **41(2)**:330-336.

Tillman, D. 1987. The importance of the mechanisms of interspecific competition. *The American Naturalist* **129(5)**:769-774.

Toft, C.A. 1985. Resource partitioning in amphibians and reptiles. *Copeia* 1-21.

Turk, P.A., Wyszynski, N.N., Powell, R., and Henderson, R.W. 2010. Population densities and water-loss rates of *Gymnophthalmus pleii*, *Gymnophthalmus underwoodi*

(Gymnophthalmidae), and *Sphaerodactylus fantasticus fuga* (Sphaerodactylidae) on Dominica, West Indies. *Salamandra* **46(3)**:125-130.

Vanhooydonck, B., Van Damme, R., and Aerts, P. 2000. Ecomorphological correlates of habitat partitioning in Corsican lacertid lizards. *Functional Ecology* **14**:358-368.

Vitt, L.J., Pianka, E.R., Cooper, W.E., and Schwenk, K. 2003. History and the global ecology of squamate reptiles. *American Naturalist* **162**:44-60.

Vitt, L.J., Sartorius, S.S., Aviles-Pires, T.C., Zani, P.A., and Esposito, M.C. 2005. Small in a big world: ecology of leaf-litter geckos in new world tropical forests. *Herpetological Monographs* **19(1)**:137-152.

Vitt, L.J., and Caldwell, J.P. 2014. *Herpetology*. Academic press. **4th edition**: 30.

Werner, Y.L., Takahashi, H., Yasukawa, Y. and Ota, H. 2006. Factors affecting foraging behavior, as seen in a nocturnal ground lizard, *Goniurosaurus kuroiwae kuroiwae*. *Journal of Natural History* **40(7-8)**:439-459.

Table 1. Substrate Type use between *Sphaerodactylus nicholsi* and *S. roosevelti*

BG-Bare Ground, M-Mixed, O-Other

Significant differences exist in the substrate type selection by species

(p-value < 0.0001). *Sphaerodactylus nicholsi* predominantly selects Leaf litter (LL) while *S. roosevelti* selects vegetation (V).**Contingency table**

Absolute frequency

In columns: Substrate Type

Species	BG	LL	M	O	V	Total
<i>S.nicholsi</i>	98	381	68	15	105	667
<i>S.roosevelti</i>	36	6	8	8	66	124
Total	134	387	76	23	171	791

Relative frequency by rows

In columns: Substrate Type

Species	BG	LL	M	O	V	Total
<i>S.nicholsi</i>	0.15	0.57	0.10	0.02	0.16	1.00
<i>S.roosevelti</i>	0.29	0.05	0.06	0.06	0.53	1.00
Total	0.17	0.49	0.10	0.03	0.22	1.00

Relative frequency (total)

In columns: Substrate Type

Species	BG	LL	M	O	V	Total
<i>S.nicholsi</i>	0.12	0.48	0.09	0.02	0.13	0.84
<i>S.roosevelti</i>	0.05	0.01	0.01	0.01	0.08	0.16
Total	0.17	0.49	0.10	0.03	0.22	1.00

Statistic	Value	df	p-value
Chi-square (Pearson)	146.94	4	<0.0001
Chi-square (ML-G2)	160.19	4	<0.0001
Contingency Coef. (Cramer)..	0.30		
Contingency Coef. (Pearson)..	0.40		

Table 2. Comparison Substrate Type “Other” between *Sphaerodactylus nicholsi* and *S. roosevelti*

D-Debris, R-Rock, TM-Termite Mound, TT-Tree trunk

No significant differences exist in “Other” substrate use category between species (p-value 0.2280).

Both species use termite mounds within this category of substrate.

Contingency table

Absolute frequency

In columns: Other Type

Species	D	R	TM	TT	Total
<i>S.nicholsi</i>	2	2	9	2	15
<i>S.roosevelti</i>	0	0	8	0	8
Total	2	2	17	2	23

Statistic	Value	df	p-value
Chi-square (Pearson)	4.33	3	0.2280
Chi-square (ML-G2)	6.21	3	0.1017
Contingency Coef. (Cramer)..	0.31		
Contingency Coef. (Pearson)..	0.40		

Table 3. *Sphaerodactylus roosevelti* substrate type: Vegetation Selection

Significant differences exist in the vegetation selected by *S. roosevelti* (p-value <0.0001). *Sphaerodactylus roosevelti* predominantly selects *Fymbristylis cymosa* (F), Followed by *Batis maritima* (B), then *Sesuvium* sp. (S).

Contingency table

Absolute frequency

Substrate	Total	Percentage
B	18	27.27
F	45	68.18
S	3	4.55
Total	66	100.00

Statistic	Value	df	p-value
Chi-square (Pearson)	41.18	2	<0.0001
Chi-square (ML-G2)	45.23	2	<0.0001
Contingency Coef. (Cramer)..	0.79		
Contingency Coef. (Pearson)..	0.62		

Table 4. Identification of Vegetation Present at *Sphaerodactylus* Macro-Habitat

Identified with the assistance of Mrs. Jeanine Vélez, M.S. - UPR Herbarium

Scientific name	Common name
<i>Avicennia germinans</i> (L.) L.	Black Mangrove
<i>Batis maritima</i> L.	Turtleweed, Beachwort, Pickleweed
<i>Cactacea</i> spp. (several)	Cactus
<i>Capparis spinosa</i> L.	Caper Bush, Flinders Rose
<i>Colubrina elliptica</i> (Sw.)Briz & Stern	Mabi
<i>Commicarpus scandens</i> (L.) Standl.	N/A
<i>Conocarpus erectus</i> L.	Button Mangrove
<i>Cyperus ochraceus</i> Vahl.	Pond Flatsedge
<i>Fimbristylis cymosa</i> R. Br	Hurricane Grass
<i>Gossypium</i> sp.	Cotton
<i>Heliotropium crispiflorum</i> Urb.	N/A
<i>Jacquinia berteroi</i> Spreng.	N/A- Unresolved name
<i>Laguncularia racemosa</i> (L.) C.F. Gaertn.	White Mangrove
<i>Phytolacca</i> sp.	Pokeweeds
<i>Pisonia subcordata</i> Sw.	Water Mampoo
<i>Pithecellobium unguis cati</i> (L.) Benth.	Cat's Claw
<i>Prosopis</i> sp.	Mesquite
<i>Rivina humilis</i> L.	Pigeonberry, Bloodberry Rougeplant
<i>Sesuvium portulacastrum</i> (L.) L.	Shoreline Purslane
<i>Thespesia populnea</i> (L.) Sol.ex correa	Indian Tulip Tree, Pacific Rosewood
<i>Ziziphus reticulata</i> (Vahl) DC.	N/A

Table 5. Comparison Leaf litter Depth (cm) selection between *Sphaerodactylus nicholsi* and *S. roosevelti*

No significant differences exist in the leaf litter depth selection by species (p-value 0.1677).

Species	N	Mean	SD	W	P-value
<i>S. nicholsi</i>	381	2.69	1.38		
<i>S. roosevelti</i>	7	2.07	1.30		
				959.00	0.1677

Table 6. Comparison of Overstory cover (%) selection between *Sphaerodactylus nicholsi* and *S. roosevelti*.

Significant differences exist in the mean over story cover selected by species (p-value <0.001). *Sphaerodactylus nicholsi* selected higher over story cover areas, than *S. roosevelti*.

Species	N	Mean	SD	W	P-value (2 Tails)
<i>S. nicholsi</i>	664	84.38	337.49		
<i>S. roosevelti</i>	123	23.10	35.97	22701.00	<0.0001

Table 7. Comparison of Temporal Category selection between *Sphaerodactylus nicholsi* and *S. roosevelti*

AM-Morning

Significant differences exist in temporal category selection by species (p-value <0.0001).

Sphaerodactylus nicholsi predominantly selected afternoon (PM), while *S. roosevelti* selected night time (Night).

Contingency table

Absolute frequency

In columns:Time category

Species	AM	Night	PM	Total
<i>S.nicholsi</i>	214	148	304	666
<i>S.roosevelti</i>	16	101	6	123
Total	230	249	310	789

Relative frequency by rows

In columns:Time category

Species	AM	Night	PM	Total
<i>S.nicholsi</i>	0.32	0.22	0.46	1.00
<i>S.roosevelti</i>	0.13	0.82	0.05	1.00
Total	0.29	0.32	0.39	1.00

Relative frequency (total)

In columns:Time category

Species	AM	Night	PM	Total
<i>S.nicholsi</i>	0.27	0.19	0.39	0.84
<i>S.roosevelti</i>	0.02	0.13	0.01	0.16
Total	0.29	0.32	0.39	1.00

Statistic	Value	df	p-value
Chi-square (Pearson)	174.95	2	<0.0001
Chi-square (ML-G2)	171.31	2	<0.0001
Contingency Coef. (Cramer)..	0.33		
Contingency Coef. (Pearson)..	0.43		

Table 8. *Sphaerodactylus roosevelti* Body Condition Index (BCI)

There exists a linear relationship between weight and SVL in *S. roosevelti* (p-value 0.0104).

Linear Regression

Variable	N	R ²	Adj R ²	PMSE	AIC	BIC
Weight (g)	60	0.11	0.09	0.03	-49.65	-43.37

Regression coefficients

Coef	Est.	S.E.	LL(95%)	UL(95%)	T	p-value
const	0.37	0.26	-0.14	0.89	1.46	0.1497
SVL Length (mm)	0.02	0.01	0.01	0.04	2.65	0.0104

Analysis of variance table (Partial SS)

S.V.	SS	df	MS	F	p-value
Model.	0.17	1	0.17	7.01	0.0104
SVL Length (mm)	0.17	1	0.17	7.01	0.0104
Error	1.39	58	0.02		
Total	1.56	59			

Table 9. *Sphaerodactylus nicholsi* Body Condition Index (BCI)

There exists a linear relationship with the SVL and weight in *S. nicholsi* (p-value <0.0001).

Linear Regression

Variable	N	R ²	Adj R ²	PMSE	AIC	BIC
LN_Weight (g)	307	0.13	0.13	0.11	181.25	192.43

Regression coefficients

Coef	Est.	S.E.	LL(95%)	UL(95%)	T	p-value
const	-8.12	0.96	-10.01	-6.24	-8.48	<0.0001
LN SVL Length (mm)	2.19	0.32	1.56	2.82	6.83	<0.0001

Analysis of variance table (Partial SS)

S.V.	SS	df	MS	F	p-value
Model.	4.86	1	4.86	46.59	<0.0001
LN_SVL Length (mm)	4.86	1	4.86	46.59	<0.0001
Error	31.81	305	0.10		
Total	36.67	306			

Table 10. Temperature (°C) selection between *Sphaerodactylus nicholsi* and *S. roosevelti*

Significant differences exist in the temperature predominantly selected by species (T-Test, p-value <0.0001). *Sphaerodactylus nicholsi* was predominantly found in lower mean temperatures when compared with *S. roosevelti*.

Species	n	Mean	LL(95)	UL	P Varhom	T	P-value
<i>S. nicholsi</i>	199	26.77					
<i>S. roosevelti</i>	112	27.96					
			-1.69	-0.69	0.4292	-4.67	<0.0001

Table 11. *Sphaerodactylus nicholsi* age category substrate type selection

A-Adult, JV-Juvenile, H-Hatchling

BG-Bare Ground, LL-Leaf Litter, M-Mixed, O-other, V-vegetation

Significant differences exist in the type of substrate selected by age category (p-value <0.001). Secondary substrate type selected differed by age. Adults selected vegetation, while juveniles selected mixed and hatchling bare ground.

Absolute frequency

In columns:Substrate Type

Age category	BG	LL	M	O	V	Total
A	63	170	31	9	84	357
H	16	63	12	2	9	102
JV	18	148	25	4	12	207
Total	97	381	68	15	105	666

Relative frequency by rows

In columns:Substrate Type

Age category	BG	LL	M	O	V	Total
A	0.18	0.48	0.09	0.03	0.24	1.00
H	0.16	0.62	0.12	0.02	0.09	1.00
JV	0.09	0.71	0.12	0.02	0.06	1.00
Total	0.15	0.57	0.10	0.02	0.16	1.00

Statistic	Value	df	p-value
Chi-square (Pearson)	52.63	8	<0.0001
Chi-square (ML-G2)	56.10	8	<0.0001
Contingency Coef. (Cramer)..	0.16		
Contingency Coef. (Pearson)..	0.27		

Table 12 . Comparison of over-story cover (%) selection by *Sphaerodactylus nicholsi* age categories

A-Adult, JV-Juvenile, H-Hatchling

Significant differences exist in over –story cover selection by age categories (p-value <0.0001). Adults selected the lowest over-story cover (%) when compared with Juveniles and Hatchling.

Variable	age category	N	Means	S.D.	Medians	H	p-value
Cover (%)	A	355	59.64	41.26	87.68	51.40	<0.0001
	H	102	85.25	24.65	93.96		
	JV	206	84.64	25.01	94.96		

Treat.	Ranks	
A	281.07	A
H	381.78	B
JV	396.51	B

Means with a common letter are not significantly different ($p > 0.05$)

Table 13 . Comparison of Leaf Litter Depth (cm) selection by *Sphaerodactylus nicholsi* age categories

A-Adult, JV- Juveniles, H- Hatchling

No significant differences exist between LL depth selection and age categories (p-value 0.2031).

Variable	age category	N	Means	S.D.	Medians	H	p-value
LL depth (cm)	A	170	2.74	1.36	2.50	3.14	0.2031
	H	63	2.35	1.00	2.50		
	JV	148	2.78	1.52	2.75		

Table 14. Comparison of *Sphaerodactylus nicholsi* morphometrics (SVL and TL (mm);Weight (g)) by Age categories

A-Adult, JV- Juveniles, H-Hatchling

SVL- snout vent length/ TL-tail length

Significant differences exist in Snout vent, tail length and weight between all age categories (p-value <0.0001). In all instances, adults had the larger mean, juveniles the intermediate mean and hatchlings the smallest mean.

Variable	age category	N	Means	S.D.	Medians	H	p-value
SVL (mm)	A	357	20.08	1.22	20.03	531.27	<0.0001
	H	102	11.62	0.83	11.62		
	JV	207	15.90	1.46	16.07		

Variable	age category	N	Means	S.D.	Medians	H	p-value
TL (mm)	A	357	16.97	6.23	17.61	230.47	<0.0001
	H	102	9.15	2.74	9.50		
	JV	207	14.29	3.74	14.58		

Variable	age category	N	Means	S.D.	Medians	H	p-value
Weight (g)	A	357	0.23	0.07	0.20	165.4	<0.0001
	H	16	0.10	0.00	0.10		
	JV	189	0.14	0.05	0.10		

Table 15. Comparison of Temporal category selection by *Sphaerodactylus nicholsi* age categories

A-Adult, JV-Juveniles, H-Hatchling

PM-Afternoon

Significant differences exist in the secondary temporal category selected between age categories (p-value <0.0001). Adults selected night as secondary temporal category, while Juveniles and hatchlings selected morning (AM).

Contingency table

Species = *S. nicholsi*

Absolute frequency

In columns:Time category

category	AM	Night	PM	Total
A	107	112	138	357
H	33	15	54	102
JV	74	21	112	207
Total	214	148	304	666

Relative frequency by rows

In columns:Time category

category	AM	Night	PM	Total
A	0.30	0.31	0.39	1.00
H	0.32	0.15	0.53	1.00
JV	0.36	0.10	0.54	1.00
Total	0.32	0.22	0.46	1.00

Relative frequency (total)

In columns:Time category

category	AM	Night	PM	Total
A	0.16	0.17	0.21	0.54
H	0.05	0.02	0.08	0.15
JV	0.11	0.03	0.17	0.31
Total	0.32	0.22	0.46	1.00

Statistic	Value	df	p-value
Chi-square (Pearson)	39.25	4	<0.0001
Chi-square (ML-G2)	41.50	4	<0.0001
Contingency Coef. (Cramer	0.14		
Contingency Coef. (Pearson)	0.24		

Table 16. Comparison substrate type selection by *Sphaerodactylus roosevelti* age categories

A-Adult, JV- Juvenile, H- Hatchlings

LL-Leaf litter, M-Mixed, O-other

Significant differences exist in the substrate type selected by age categories of *S. roosevelti* (p-value 0.0175). Adults and Juveniles predominantly selected vegetation (V), while hatchlings selected bare ground (BG).

Absolute frequency

In columns:Substrate Type

Age category	BG	LL	M	O	V	Total
A	20	5	3	8	45	81
H	14	1	3	0	9	27
JV	2	0	2	0	12	16
Total	36	6	8	8	66	124

Relative frequency by rows

In columns:Substrate Type

Age category	BG	LL	M	O	V	Total
A	0.25	0.06	0.04	0.10	0.56	1.00
H	0.52	0.04	0.11	0.00	0.33	1.00
JV	0.13	0.00	0.13	0.00	0.75	1.00
Total	0.29	0.05	0.06	0.06	0.53	1.00

Statistic	Value	df	p-value
Chi-square (Pearson)	18.54	8	0.0175
Chi-square (ML-G2)	21.34	8	0.0063
Contingency Coef. (Cramer)..	0.22		
Contingency Coef. (Pearson)..	0.36		

Table 17. Comparison over-story cover selection between *Sphaerodactylus roosevelti* age categories

A-Adult, JV-Juvenile, H- Hatchling

Significant differences exist in the over story cover selection between age categories

(p-value 0.0373). Adults had the largest cover percent mean, while hatchlings had the lowest.

Variable	age category	N	Means	S.D.	Medians	H	p-value
Cover (%)	A	80	29.09	38.24	0.00	4.96	0.0373
	H	27	10.44	28.14	0.00		
	JV	16	14.53	29.83	0.00		

Treat.	Ranks	
H	50.24	A
JV	56.41	A B
A	67.09	B

Means with a common letter are not significantly different ($p > 0.05$)

Table 18. Comparison Leaf Litter depth (cm) selection by *Sphaerodactylus roosevelti* age categories

A-Adults, H-Hatchlings

No significant differences exist in the leaf litter depth selection by age categories (p-value 0.7143).

Variable	age category	N	Means	S.D.	Medians	H	p-value
LL depth(cm)	A	6	2.25	1.33	2.00	1.00	0.7143
	H	1	1.00	0.00	1.00		

Table 19. Comparison of *Sphaerodactylus roosevelti* Morphometrics (SVL and TL (mm);Weight (g) by age category

A-Adult, JV-Juveniles and H-Hatchling

Significant differences exist in all three morphometric parameters by age categories (p-value <0.0001).

Adults had greater mean for SVL,TL and Weight, while Juveniles had intermediate mean and hatchling the lowest.

Variable	age category	N	Means	S.D.	Medians	H	p-value
SVL (mm)	A	81	32.19	3.74	32.44	78.41	<0.0001
	H	27	19.18	2.13	19.26		
	JV	16	25.26	1.62	24.70		

Variable	age category	N	Means	S.D.	Medians	H	p-value
TL (mm)	A	81	31.06	7.87	32.21	48.91	<0.0001
	H	27	17.26	5.23	17.80		
	JV	16	26.18	8.20	28.03		

Variable	age category	N	Means	S.D.	Medians	H	p-value
Weight (g)	A	81	1.02	0.25	1.10	73.86	<0.0001
	H	27	0.22	0.07	0.20		
	JV	16	0.50	0.20	0.50		

Table 20. Seasonal prevalence of *Sphaerodactylus nicholsi* by age category

Adult- Adults, JV- Juveniles, H-Hatchling

F-Fall, SP-Spring, SU-Summer, W-Winter

Significant differences exist in the prevalence of age categories by seasons of the year (p-value <0.0001). Adults were predominantly found in winter (W), while Juveniles (JV) and Hatchlings (H) were predominant during fall (F).

Contingency table
Species = S. nicholsi

Absolute frequency

In columns: Season

age category	F	SP	SU	W	Total
A	59	86	91	121	357
H	29	28	22	23	102
JV	70	27	54	56	207
Total	158	141	167	200	666

Relative frequency (total)

In columns: Season

age category	F	SP	SU	W	Total
A	0.09	0.13	0.14	0.18	0.54
H	0.04	0.04	0.03	0.03	0.15
JV	0.11	0.04	0.08	0.08	0.31
Total	0.24	0.21	0.25	0.30	1.00

Statistic	Value	df	p-value
Chi-square (Pearson)	32.33	6	<0.0001
Chi-square (ML-G2)	33.12	6	<0.0001
Contingency Coef. (Cramer)..	0.13		
Contingency Coef. (Pearson)..	0.22		

Table 21. Seasonal prevalence of *Sphaerodactylus roosevelti* by age category

Adult- Adults, JV- Juveniles, H-Hatchling

F-Fall, SP-Spring, SU-Summer, W-Winter

Significant differences exist in the prevalence of age categories by seasons of the year (p-value 0.0323). Adults and juveniles were predominantly found in fall (F), while Hatchlings (H) were predominant during spring (SP).

Species = S. roosevelti

Absolute frequency

In columns:Season

age category	F	SP	SU	W	Total
A	29	14	17	21	81
H	4	11	5	7	27
JV	8	6	1	1	16
Total	41	31	23	29	124

Relative frequency (total)

In columns:Season

age category	F	SP	SU	W	Total
A	0.23	0.11	0.14	0.17	0.65
H	0.03	0.09	0.04	0.06	0.22
JV	0.06	0.05	0.01	0.01	0.13
Total	0.33	0.25	0.19	0.23	1.00

Statistic	Value	df	p-value
Chi-square (Pearson)	13.77	6	0.0323
Chi-square (ML-G2)	15.22	6	0.0186
Contingency Coef. (Cramer)..	0.19		
Contingency Coef. (Pearson)..	0.32		

Table 22. Comparison between male and female *Sphaerodactylus roosevelti* morphometrics - SVL and TL (mm); Weight (g)

F- Female/ M- Male

Significant differences exist in the Tail Length of male and females, with males having longer tails than females (p-value 0.0361). No significant differences were observed in snout vent length (SVL) or weight between genders.

Variable	Sex	N	Means	S.D.	Medians	H	p-value
SVL (mm)	F	50	32.36	3.21	32.34	1.51	0.2184
SVL (mm)	M	25	33.25	2.77	32.68		

Variable	Sex	N	Means	S.D.	Medians	H	p-value
TL (mm)	F	50	30.28	8.43	31.32	4.39	0.0361
TL (mm)	M	25	33.91	5.78	35.45		

Variable	Sex	N	Means	S.D.	Medians	H	p-value
Weight (g)	F	50	1.04	0.24	1.05	2.62	0.0974
Weight (g)	M	25	1.11	0.11	1.10		

Table 23. *Sphaerodactylus roosevelti* nocturnal prevalence by Lunar Phases

Significant differences exist in prevalence by lunar phase (p-value 0.0027).
Sphaerodactylus roosevelti was more prevalent during New Moon phase than any other lunar phase.

Contingency table

Absolute frequency

In columns: Moon Phases

Species	First Quarter	Full Moon	Last Quarter	New Moon	Total
<i>S. roosevelti</i>	21	23	16	41	101
Total	21	23	16	41	101

Relative frequency by rows

In columns: Moon Phases

Species	First Quarter	Full Moon	Last Quarter	New Moon	Total
<i>S. roosevelti</i>	0.21	0.23	0.16	0.41	1.00
Total	0.21	0.23	0.16	0.41	1.00

Relative frequency (total)

In columns: Moon Phases

Species	First Quarter	Full Moon	Last Quarter	New Moon	Total
<i>S. roosevelti</i>	0.21	0.23	0.16	0.41	1.00
Total	0.21	0.23	0.16	0.41	1.00

Statistic	Value	df	p-value
Chi-square (Pearson)	14.13	3	0.0027
Chi-square (ML-G2)	13.12	3	0.0044
Contingency Coef. (Cramer)..	0.37		
Contingency Coef. (Pearson)			



Research and Monitoring Special Use Permit Application

Refuge Name: Cabo Rojo

Address: P.O. Box 812 Boquerón, PR 00622

Attn: (Refuge Official) Oscar Diaz

E-Mail: oscar_diaz@fws.gov

Phone #: 787-851-7258

For Official Use Only

Approved Permit #: 2016-03

Station #: 41521

Permit Term: from 10/30/15 to 10/30/16

Note: We do not require all information for each Research project. See instructions at the end of the notice and contact the refuge to determine applicability of a particular item. Attach additional sheets if the text spaces provided are inadequate.

1) Identify the type of Permit you are applying for: New ☐ Renewal ☒ Modification ☐ Other ☐

Applicant Information

2) Principal investigator: Rhianna F. Smith Dorr 3) Is curriculum vitae or resume attached? Yes ☐ No ☒

4a) Affiliation/Sponsoring Organization: University of Puerto Rico at Mayagüez (RUM)

4b) Relationship to affiliation/sponsoring organization (professor, staff, student, etc.): Graduate student, Biology Dept.

5) Street Address: 155 La Paz St. Bo. París

6) City/State/Zip: Mayagüez, PR 00680

7) Phone #: 787-310-1290 8) Fax #: none 9) E-mail: rhianna.faiht@gmail.com

10) List known assistants/subcontractors/subpermittees: (Only required if the assistants/subcontractors/subpermittees will be operating on the refuge without the permittee being present.)

Name	Address	Phone #
N/A		

Project Information

11) Title of project: Ecological comparison between two species of Sphaerodactylus at the saltflats

12a) Is full research proposal required? Yes ☐ No ☒ 12b) Is full research proposal attached? Yes ☐ No ☒

Note: Depending on the research and monitoring project for which you are requesting a permit, we may ask you for the following project information (13 -25) if it is not included in your research proposal, or if you have not provided a full research proposal with this application. Please contact the specific refuge where the activity is being conducted to determine what information is required.

Attach additional sheets to the application if the text spaces provided are inadequate.