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Does the Matrix Matter? A Comparison on Phenology and Habitat utilization of Two Treefrog Species in the Big Cypress National Preserve

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DOES THE MATRIX MATTER?

A COMPARISON OF PHENOLOGY AND HABITAT UTILIZATION

OF TWO TREEFROG SPECIES IN THE BIG CYPRESS NATIONAL PRESERVE

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Monica Isola

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To: Dean Kenneth G. Furton
College of Arts and Sciences

This thesis, written by Monica Isola, and entitled Does the matrix matter? A comparison of Phenology and Habitat Utilization of Two Treefrog Species in the Big Cypress National Preserve, having been approved in respect to style and intellectual content, is referred to you for judgment.

We have read this thesis and recommend that it be approved.

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The thesis of Monica Isola is approved.

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Florida International University, 2011

DEDICATION

I dedicate this thesis to my family who supported and encouraged me all throughout this journey. I specially want to dedicate it to my parents, Mirta and Enrique, without whose unconditional love and motivation I wouldn't have gotten to where I am, and learned and grown so much along the way.

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ABSTRACT OF THE THESIS

DOES THE MATRIX MATTER?

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Professor Maureen A. Donnelly, Major Professor

Habitat loss and fragmentation are some of the causes of biodiversity decline. Naturally fragmented landscapes serve as analogues to anthropogenically fragmented landscapes. Recent studies have shown that the matrix between patches has an important role in the dynamics of patch-dwelling species. I studied phenology and habitat utilization of *Hyla cinerea* and *Hyla squirella*, the two most common yet understudied frogs, in two patchy landscapes of the Big Cypress National Preserve. Frogs were sampled in five domes and in their adjacent matrix, monthly, between 2006 and 2008. Using nighttime visual encounter surveys, specimens encountered were identified to species, and perch type, perch height and capture location were recorded. Analysis showed differences in abundance and habitat use patterns between patches and matrices for the two species across the two landscapes. These differences indicate that the matrix is important in shaping patterns of abundance and habitat use in fragmented landscapes.

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INTRODUCTION

Habitat loss and fragmentation through anthropogenic deforestation are some of the causes of biodiversity decline (Blaustein et al. 1994, Bell and Donnelly 2006, Cushman 2006, Fischer and Lindenmayer 2007). The study of naturally fragmented landscapes is of great use for application in conservation and restoration efforts because they provide models for what might happen as a habitat is fragmented. Only relatively recently has there been a focus on the variety of matrix qualities and how the matrix affects these patch communities (Ricketts 2001, Haynes and Cronin 2003, Kupfer et al. 2006, Watling et al. 2010).

Island biogeography and metacommunity studies have been the foundation for ecologists trying to understand community dynamics among islands or in patchy landscapes that functionally resemble islands. Patch (island) habitat, is any relatively hospitable habitat surrounded by a matrix (ocean) of inhospitable habitat. These theories have traditionally focused on the island or its terrestrial version, the patch, looking specifically into distance between patches, patch area and shape; and considered the ocean/matrix characteristics unimportant; the matrix is only a uniform void or a distance between the focal patches (MacArthur and Wilson 1967, Simberloff and Wilson 1969, Danielson 1992, Watling and Donnelly 2006, Watling and Donnelly 2008, Watling et al. 2010).

More recently, researchers have put some focus on the matrix and realize that intrinsic matrix characteristics do have an effect on the dynamics and patterns of populations and communities that inhabit the patches (Ricketts 2001, Haynes and Cronin 2003, Kupfer et al. 2006, Watling et al. 2010). The matrix surrounding different islands may differ in "permeability." The permeability of a landscape is defined as how easy it is for animals to move across it. Permeability varies across animal taxa (Debinski and Holt 2000, Berry et al. 2005, Ewers and Didham 2006, Kuefler et al. 2010). For example a habitat is more permeable for a deer if vegetation is open allowing deer to easily walk through it, whereas a habitat with thick vegetation is more permeable for an amphibian if moisture is retained in that environment. Matrix heterogeneity, therefore, influences connectivity, patterns of abundance and occupancy between and within patches (Watling et al. 2010).

The Big Cypress National Preserve (BCNP) is a federally protected parcel within the greater Everglades ecosystem and part of the preserve includes discrete habitat patches (Figure 1). The Raccoon Point area, located along the southeastern border of the Big Cypress provides an opportunity to study natural patches. Small depressional forested wetlands known as cypress domes are distinctive features of the Raccoon Point landscape. Trees are taller in the center of the domes, and decrease in size towards the periphery (Ewel and Odum 1984). Trees surround the deepest part of the wetland and the center of the dome is wettest for the longest part of the hydroperiod (>250 days/year; ~70 cm of water above ground in the wet season) (Duever et al. 1986, Duever et al. 2005). Vegetation in domes is dominated by pond cypress, *Taxodium ascendens* and few hardwood species: cocoplum (*Chrisobalanus icaco*), epiphytes such as orchids and bromeliads (e.g., *Tillandsia* sp.), and aquatic plants towards the center of domes such as sawgrass (*Cladium jamaicense*) and Alligator Flag (*Thalia geniculata*) (Duever et al. 1986, Duever et al. 2005). The domes are surrounded by a variety of 'matrix' types. Herein I use matrix to refer to the habitat type that surrounds a particular dome. The matrix varies from 'heterogeneous' (a mix of vegetation types) to 'pure' cypress prairie and 'pure' pine rockland matrix types. For the purpose of this study, we selected domes surrounded by a single matrix type: cypress prairies or pine rocklands so we may truly compare the effects of two different matrix types on the amphibian communities. Rice et al. (2005) established that there are thriving populations of two frogs, *Hyla cinerea* and *Hyla squirella* in BCNP, and my thesis focuses on these species.

Amphibian occurrence is generally explained by variation in hydrology (McDiarmid 1994, Wells 2007). If it were the case that hydrology is the most important driver of patterns of amphibian occurrence then I would find these species more frequently in cypress domes than in the surrounding matrices, also there should be no difference in the abundance of frogs in domes surrounded by different matrix types. Instead, if matrix characteristics like vegetation structure have an influence on frog abundance then I would expect to find a difference between domes embedded in different matrix types.

The treefrog family Hylidae is a widespread family of anurans and the subfamily Hylinae has the widest distribution within the family (Faivovich et al. 2005). The Green Treefrog (*Hyla cinerea*) and the Squirrel Treefrog (*Hyla squirella*) are two species in this subfamily that are common in southeastern United States (Conant and Collins 1991, Mitchell and Lannoo 2005, Redmer and Brandon 2005)(See figure 2). These two species are extremely common in the Everglades ecosystem (Rice et al. 2005). With greatly overlapping distributions, *Hyla cinerea* inhabits the southeastern coastal plain from Delmarva Peninsula through Florida down to the Keys; and to the west, through the Gulf Coast Plain reaching a northern limit in southern Illinois, to south and east of Texas

(Conant and Collins 1991, Aresco 1996). *Hyla squirella* ranges from southeastern Virginia to the Keys and west through the Gulf Coast Plain to Texas extending into Corpus Christi Bay (Conant and Collins 1991, Gunzburger, 2006, Binckley and Resetarits Jr., 2007). The overlap of the two species is shown in Figure 2. Both species are known for being abundant throughout their range and particularly in BCNP (Rice et al. 2005). They have been surveyed in several places in Florida (Duellman and Schwartz 1958, Donnelly et al. 2001, Enge 2005, Smith et al. 2006, Dodd and Barichivich 2007, Pham et al. 2007, Liner et al. 2008) and used as specimens in several research studies (Höble and Gerhardt 2003, Baber and Babbitt 2004, Gunzburger 2006, Gunzburger 2007). However, there are sparse data on natural populations of both species in South Florida (Donnelly et al. 2001).

In an attempt to restore some capacity and services of the Everglades ecosystem, the largest ecosystem restoration project in the world is taking place in the Everglades today. The Comprehensive Everglades Restoration Plan (CERP) intends to capture freshwater that has been channeled to the sea and redirect it into the ecosystem to restore natural water flow and level through the Everglades. The restoration will eventually restore historic landscape connectivity, and biodiversity should be better protected when the project is complete (UCOE 2005). Drastic modification of water quantity and quality has likely affected amphibian diversity and abundance in the region (McDiarmid 1994).

Amphibians are an important component of wetland communities, and of southeastern United States wetlands in particular (Bennett et al. 1980). Amphibians are also very good bioindicators of habitat “health” and any changes in the environment surrounding them (McDiarmid 1994, Welsh and Ollivier 1998). Because they have thin permeable skin, which they use for respiration and water absorption, amphibians are very susceptible to environmental changes; any deterioration in habitat quality will most likely be reflected on amphibians, either in abundance (lower population size and /or species richness) or physiology (i.e., smaller adults, shorter time to metamorphosis, etc.) (Leips and Travis 1994, Bridges and Semlitsch 2001, Gerlanc and Kaufman 2005, Ugarte et al. 2005, Rohr et al. 2008). Because amphibians, such as frogs, are thought to be good bioindicators, it is important to learn how their populations live in this system now to provide a baseline for estimating restoration success in the future.

Because so little is known of these two common species, I used data gathered by me and other researchers as part of a pilot study that took place at Raccoon Point, BCNP, to describe patterns of abundance, seasonal variation in microhabitat use and determine if these species differ in matrix use by comparing domes to matrix. The objectives of this study were to test the following hypotheses:

Ha_1: Patterns of abundance differ between patch and matrix in the cypress prairie and the pine rockland, and there is no interaction between response and matrix type.

Ha_2: Patterns of abundance of *H. cinerea* and *H. squirella* change during the year.

Ha_3: Habitat use (perch type) varies between species in domes.

Ha_4: Patterns of vertical distribution in domes are different for each species.

I expect the matrix to have an influence in how the frogs use the patches and therefore, I expect differences between different matrices to be reflected in how these frogs use their space. I expect that because the cypress dome patches hold water for the longest time of the year and subsequently have a richer, more complex and hospitable vegetation structure, this is where frogs will be found most often. Since the cypress prairie matrix is more open, and perhaps more inhospitable to frogs than the pine rockland that has more shrubs and palms with a vegetation structure that may be more hospitable, providing frogs with resting spots, I expect to find more frogs in the pine rockland than in the cypress prairie and in consequence, more in the pine rockland patches than in the cypress prairie patches. Also, since these frogs are so similar and closely related, I expect them to somehow partition the common space they share within the cypress domes.

METHODS

Study Area Description

Sampling was completed between April 2006 and November 2008 (Table 1) in two sites accessed by the Eleven Mile Road in the Raccoon Point Area of the Big Cypress National Preserve (BCNP). Cypress domes were our focal patch habitats. Sites were selected to maximize the distinction between patch and matrix. One site had five domes surrounded by cypress prairie and the other had five domes embedded in pine rockland (Figure 3).

The cypress prairie vegetation is characterized by predominance of dwarf pond cypress, *Taxodium ascendens* and understory species that include ferns, epiphytes, sedges, grasses and aquatic plants (Duever et al. 1986). The hydroperiod lasts 50-150 days and these sites are flooded with 30-60 cm of water in the wet season (Duever et al. 1986).

Pine rocklands are fire-dependent pine forests that are dominated by South Florida Slash Pine (*Pinus elliotti* var. *densa*), with saw palmetto, shrubs, and grasses in the understory (Sah et al. 2007). The Pine rocklands are a rare and threatened landscape type.

They are unique to Florida and the Bahamas and, although protected, are threatened by various pressures as limestone drilling, fire suppression and exotic species invasion (Liu and Koptur 2003, Snyder et al. 2005). They have a short hydroperiod of 20-60 days with some flooding which is shorter than it is in the cypress prairie. (Duever et al.1986).

The cypress prairie is characterized by having a longer hydroperiod than the pine rockland (Duever *et al*. 1986). On the other hand, the pine rockland has a vegetation structure that may be hospitable to amphibians because the greater plant density and variety of species that make up the vegetation may give small animals a greater chance of finding refuge than does the cypress prairie which hosts reduced plant species richness. Hydrological characteristics ensure that domes in cypress prairie are more connected through water (Nowakowski et al. unpublished manuscript) and frogs, given their amphibious nature (McDiarmid 1994), that use domes in pine rockland may use the matrix for longer annual periods.

Site selection and setup

Preliminary site selection was done with the aid of Google Earth™ and confirmed on the ground by James I. Watling and members of our laboratory group. Requirements for dome selection were: similar shape and size (at least 50 m radius), dome was completely surrounded by a single type of matrix (no “hybrids”), and at least 200 m from the nearest neighboring dome (Figs. 2 and 3).

Five cypress prairie domes and five pine rockland domes were selected. Once the dome was selected, a random entry point was selected. One 50 m transect was placed in each dome from the edge of the dome towards the center, and the transect was flagged every five meters. For every dome transect there was a matrix transect of the same length (50 m) placed adjacent to the dome. The starting point and direction of each matrix transect was determined haphazardly using a compass. The same transects were sampled during the duration of the study.

Sampling Events

Sampling took place monthly during two years from 2006 to 2008. Each sampling event took place on consecutive nights and both landscape types were sampled, and a total of 15-20 visits to each transect were made during the two-year period. There were months when sampling was not possible because of hazardous weather conditions (high risk of lightning striking) in the wet season (Table 1).

Nighttime visual encounter surveys (VES) (Crump and Scott 1994) were used to locate frogs along transects in the patches (cypress domes) and matrix. We recorded data for all individuals we encountered. Individuals found within two meters to each side of each transect and perched up to two meters above the ground were sampled using the VES sampling design. Transects were surveyed by one or two individuals.

Transect sampling

We sampled terrestrial/arboreal post-metamorphic frogs. Juveniles and adults of both species are more active at night than during the day therefore we used nighttime Visual Encounter Surveys (VES) to sample frogs during the study. All amphibians encountered during sampling were caught, identified by species, and body mass and snout-vent length (SVL) were measured. If possible, sex was recorded, and each individual was toe clipped with site-specific marks. We recorded perch height above the ground or water surface (distance from substrate) and substrate type (tree, sawgrass, palm, etc.) as well as location (matrix/dome, pine rocklands/cypress prairie) and distance along the transect. Height was defined as distance from substrate because when the land was dry, distance was measured starting from the ground, but when the land was inundated, distance was measured starting at the water surface.

DATA ANALYSIS

Patterns of abundance analysis

All data analysis was performed in SPSS 17.0 software. With the data collected for each individual encountered, a crosstabs was performed to calculate the number of frogs encountered at each site, during each monthly sample. Once these data were obtained, the hypotheses stated could be tested and analysis was performed separately for each species. Differences in mean number of frogs between landscape types and transect types (1) were analyzed using a two-way analysis of variance (ANOVA), with landscape type (with two levels: cypress prairie or pine rockland) and transect type (with two levels: dome transect or matrix transect) as the two independent variables and with number of frogs for each sample as the dependent variable. Differences in mean number of frogs between the two landscape types by seasons (2) were analyzed using a two-way ANOVA, with transect type (with two levels: dome transect or matrix transect) and season (with two levels: wet and dry) as the two independent variables and with the number of frogs of each sample as the dependent variable.

Before performing the statistical test, the data set was examined for normality and homogeneity of variance by performing a normality test, examining the residuals' distribution and performing a Levene's test for homogeneity of variance. These data were not normally distributed, as is the case with most biological data. Since these are count data, I used a square-root transformation to normalize the data. Also, since there were zeros in the data set (when there were no frogs encountered or when a site was not sampled), 0.5 was added to the original number of frogs as to eliminate all zero values. Finally, the values used for analysis were:

$$X_{transformed} = \sqrt{(X_{original} + 0.5)}$$

The transformed data were normal and variance was homogeneous.

No post hoc test could be performed because there were only two factors to each variable. So, when necessary, in case of significant differences between groups, a one-way ANOVA was performed for the specific group.

Habitat utilization (perch type) analysis

To compare substrate use between both species and to see if there was any difference in how they used different perch types, and because vegetation composition is similar among the domes, all domes were grouped and habitat utilization analysis was examined only within domes, the patch type that is common to both landscapes. For this reason, all matrix observations were eliminated for this analysis. Also, all observations where a species was not identified, or perch type was not recorded were eliminated so an accurate comparison between species could be made. All data analysis was performed in SPSS 17.0 software. A Chi-squared statistical test was used to determine if use of a perch type is independent of species (3), this is, to see if species use perch types differently. In addition, two crosstabs tables were performed with SPSS to display the number of times each species was encountered on each perch type and the percentages within species and for each perch type these counts represent.

Patterns of vertical distribution analysis

Because I wanted to determine if the surrounding matrix has an effect on how these species use the domes, patterns of vertical distribution were examined only within domes. Also, all observations where a species was not identified were eliminated so accurate comparisons between species could be made. All data analysis was performed in SPSS 17.0 software. Differences in mean perch height (distance from substrate) between species were analyzed using a two-way ANOVA statistical test with dome type (with two levels: cypress prairie dome or pine rockland dome) and species (with two levels: *H. cinerea* or *H. squirella*) as the two independent variables and with height, distance from substrate, of each sample as the dependent variable.

Before performing the statistical test, I tested for normality and homogeneity of variance. These data were not normally distributed, however when looking at the standardized residuals' histogram, they show a distribution that was approximately normal, allowing me to perform the parametric ANOVA to test the hypotheses. Also, an attempt to transform the data was made but no transformation yielded a data set normally distributed nor with residuals that approximated a normal distribution.

As in the case of the patterns of abundance analysis, no post hoc test could be performed in this analysis because there were only two levels for each variable. So, when necessary, in case of significant differences between groups, a one-way ANOVA was performed for the specific group. Since, in these cases, ANOVA assumptions were not met, then a Mann-Whitney U test was performed instead. However, both analyses yielded agreeing results with significance levels that differed only slightly, so the Mann-Whitney U test results are the ones reported in the results section.

RESULTS

Patterns of abundance

Comparisons of abundance between landscape and between transect types

Statistical analysis for *H. cinerea* showed there is a significant difference in the overall (grouping patch and matrix together) mean number of observed *H. cinerea* individuals between the cypress prairie and the pine rockland landscapes ($F_{1,396}$= 27.499; $P < 0.001$), with more frogs in the pine rockland than in the cypress prairie (Figure 4a). The mean number of *H. cinerea* frogs in the pine rockland in any sampling night was 12.175 frogs whereas in the cypress prairie it was 5.825 frogs. However, when comparing overall (grouping both landscapes) mean number of observed *H. cinerea* individuals between domes and matrices, the statistical analysis showed no significant difference ($F_{1,396}$= 0.825; $P = 0.364$).

Specifically, in the cypress prairie, *H. cinerea* shows no significant difference in abundance between domes and matrix ($F_{1, 198}$ = 3.308; $P = 0.070$). However, in the pine rockland, *H. cinerea* does present a significant difference in abundance ($F_{1, 198}$ = 6.061; $P = 0.015$), with more individuals in the matrix than in the domes. The mean number of *H.*

cinerea frogs in the pine rockland domes in any sampling night was 9.25 frogs whereas in the pine rockland matrix it was 15.1.

On the other hand, statistical analysis for *H. squirella* showed there is a significant difference in the overall (grouping patch and matrix together) mean number of observed *H. squirella* individuals between the cypress prairie and the pine rockland landscapes ($F_{1,396}$= 45.278; P < 0.001), with more frogs in the pine rockland than in the cypress prairie (Figure 4b). The mean number of *H. squirella* frogs in the pine rockland in any sampling night was 16.05 frogs whereas in the cypress prairie it was 2.5 frogs. Also, when looking at overall (grouping both landscapes) difference in abundance between domes and matrices for *H. squirella*, the statistical analysis showed there was a significant difference ($F_{1,396}$= 4.934; P < 0.001), with a greater abundance of *H. squirella* in domes than in matrices overall.

Specifically, in the cypress prairie, *H squirella* shows a significant difference in abundance between domes and matrix ($F_{1, 198}$ = 36.393; P < 0.001), with more individuals in the domes than in the matrix. The mean number of *H. cinerea* frogs in the cypress prairie domes in any sampling night was 8.65 frogs whereas in the cypress prairie matrix it was 2.5. However, in the pine rockland, *H squirella* does not present a significant difference in abundance ($F_{1, 198}$ = 0.493; P = 0.483). Table 2 summarizes the mean number of frogs in landscape and transect types for each species.

Comparisons of abundance between seasons

When looking into phenological differences in patterns of abundance of *H. cinerea*, the statistical analysis shows that there is no significant difference in *H. cinerea* abundance between the wet and dry season in the cypress prairie ($F_{1, 198} = 0.488$; $P = 0.485$). Also, there is no significant difference in *H. cinerea* abundance between domes and matrix in the cypress prairie in both seasons, in the dry season ($F_{1, 99} = 2.765$; $P = 0.098$) and in the wet season ($F_{1, 99} = 0.528$; $P = 0.468$). *Hyla cinerea* was evenly abundant all across the cypress prairie throughout the year (Figure 5a).

For *H. cinerea* in the pine rockland, the statistical analysis shows that there was a significant difference in *H. cinerea* abundance between the wet and dry season in the pine rockland ($F_{1, 198} = 5.784$; $P = 0.021$), with a greater abundance of *H. cinerea* in the dry season than in the wet season. However, although the general pattern showed that *H. cinerea* in the pine rockland was more abundant in the matrix only in the dry season ($F_{1, 99} = 4.512$; $P = 0.047$). During the wet season there is no significant difference in *H. cinerea* abundance between transect types ($F_{1, 99} = 0.817$; $P = 0.378$). So, *H. cinerea* is evenly abundant across the pine rockland in the wet season but in the dry season they are more abundant in the matrix (Figure 5a).

When looking into seasonal differences in patterns of abundance of *H. squirella*, the statistical analysis shows that there is no significant difference in *H. squirella* abundance between the wet and dry season in the cypress prairie ($F_{1, 198} = 0.101$; $P = 0.751$). Also, there is a significantly greater abundance of *H. squirella* in cypress prairie domes than in the matrix in both seasons, in the dry season ($F_{1, 99} = 15.282$; $P < 0.001$)

and in the wet season ($F_{1, 99}$ = 10.302; P = 0.001). *Hyla squirella* was more abundant in domes than in the matrix in the cypress prairie throughout the year (Figure 5b).

For *H. squirella* in the pine rockland, looking into seasonal differences in patterns of abundance, the statistical analysis shows that there is a significant difference in *H. squirella* abundance between the wet and dry season ($F_{1, 198}$ = 5.897; P = 0.016), with a greater abundance of *H. squirella* in the dry season than in the wet season. Also, *H. squirella* presents no significant difference in abundance between pine rockland domes and matrix in any season, in the dry season ($F_{1, 99}$ = 0.929; P = 0.336), nor in the wet season ($F_{1, 99}$ = 0.122; P = 0.727). So, *H. squirella*, in the pine rockland, is more abundant in the dry season than in the wet season but evenly abundant across the landscape in each season (Figure 5b).

Habitat utilization

Perch use varied between the two species (χ^2_{12} = 58.434; P < 0.001). Both species were observed perched on the same substrates but they were not found to use them in the same proportions (Figure 6). Although the three substrates that each species was observed the most on were the same, and in the same order of priority, the proportions in which each of them use the substrates are different; for example, *H. squirella* uses epiphytes 30 % of their time, followed by cocoplum 14.6% and cypress 12.2%. *Hyla cinerea* uses epiphytes 23 % of their time, followed by cocoplum 14.6% and cypress 13.7%. There is also a difference in use of Alligator flag, *H. squirella* uses it only 0.4% of the time whereas *H. cinerea* is found on it 6.7% of its times. *Hyla squirella* was found 8.9% of the time on “other trees” that include unidentified tree species and pond apple trees, instead *H. cinerea* was found on these other varieties of trees only 3.7% of their time. On the other hand, *H. squirella* only uses grass 7.8% of the time but *H. cinerea* uses it 11.6% of its time. Table 3 presents a summary of substrate use for each species.

Patterns of vertical distribution

Vertical distribution was examined solely in patches and focused on the comparison between species. There is an overall significant difference in perch height in domes for the two species, *H. cinerea* and *H. squirella* ($F_{2, 813}$; P = 0.005). In cypress prairie *H. squirella* was perched higher than *H. cinerea* but this difference was not significant (Z = -0.669; P = 0.504). However, in pine rockland differences in mean perch heights are significant (Z = -3.321; P = 0.001) where *H. squirella* used higher perches than *H. cinerea* (Figure 6).

When comparing perch height of each species between patch types, I found that *H. squirella* (Z = -0.5; P = 0.617) does not differ significantly in its perch height between the different patch types. *Hyla cinerea* used higher perches in cypress prairie than they did in pine rockland (Z = -1.99; P = 0.047).

DISCUSSION

The abundance of these two treefrogs varies in domes and matrix of the two landscapes at Raccoon Point. Both species were found in greater abundance in the pine rockland landscape than in the cypress prairie.

The two treefrog species that I examine in this study are sensitive to environmental conditions in their surrounding environment (McDiarmid 1994, Wells

2007). Because of their permeable skin they are susceptible to desiccation threats and require retreats that provide appropriate thermal and hydric conditions (McDiarmid 1994, Wells 2007), therefore fluctuations and/or variations in their environment may be reflected on them not only at a physiological level but also in terms of their abundance. For instance, it may be more likely to encounter a frog in a humid, shaded environment with well-structured vegetation than in an environment that is exposed to the sun and wind.

At the Raccoon Point in BCNP, the pine rockland matrix presents an environment with higher plant species richness than the cypress prairie matrix (Duever et al. 1986, Duever et al. 2005). If plant species richness can be used as a proxy for habitat richness, then we might assume that there is a greater contrast in vegetation structure between dome and matrix in the cypress prairie than in the pine rockland. If this is the case, the cypress prairie matrix would have an exposed, more hostile, environment and should be a less permeable environment for organisms like frogs than is the rockland matrix where vegetation structure provides more shelter and results more permeable for such animals. In these terms, this structure is more similar to that of the domes than the hostile environment of the cypress prairie matrix. My results reflect patterns as expected under these assumptions; however, measurements of environmental factors such as canopy density, ground cover, temperature and humidity should be measured and analyzed together to properly assess if this is true.

In particular, *H. cinerea* has the same abundance in domes and matrices of both landscapes; but *H. squirella*, is more abundant inside the domes in cypress prairie. Although I expected an overall tendency for both species to be found in greater abundance inside domes, this occurred only for one species (*H. squirella*) in one landscape (cypress prairie). To understand the root of these differences, further research on the nature of these landscapes and species is needed.

Looking into seasonality, although there were gaps in sampling periods, there was approximately the same number of sampling months for the wet and dry seasons. Gaps in the wet season were mostly caused by adverse weather and gaps in the dry season were mostly by logistics. Although most gaps were in the wet season, I ended up having just as many sampling months for the wet (11 months) than for the dry season (10 months), because the beginning of sampling for this study coincided with the beginning of the wet season (April 2006) and the end coincided with the onset of the dry season two years later (November 2008), this way, allowing a fair comparison between seasons.

During the wet season, in both landscapes, when the matrix between domes is flooded (Duever et al. 1986, Duever et al. 2005), these domes are more connected for organisms that are tied to water and vulnerable to desiccation like these treefrogs (McDiarmid 1994, Wells 2007), and so, such conditions should allow these organisms to move freely from dome to dome and throughout the matrix, as a more homogeneously distributed assemblage; in the dry season, as the landscapes undergo dry down (Duever et al. 1986, Duever et al. 2005) frogs should be expected to retreat from dry conditions and reside in the domes.

My results show that for both species there was no marked difference in abundance between seasons in the cypress prairie, with *H. squirella* found in greater abundance in the domes throughout the year; and there was a greater abundance in the dry season in the pine rockland landscape for both species, with *H. cinerea* in greater abundance in the matrix only in the dry season. Finding a greater abundance of frogs in the dry season than in the wet season seems paradoxical. Finding one species in greater abundance in the matrix seems like a paradox as well.

As to why, in the pine rockland, both species were found in greater abundance in the dry season instead of the wet season, and in particular *H. cinerea* was found in greater abundance in matrix, further exploration of size (svl) data by month shows that a predominance of smaller frogs were observed in the dry seasons of my study, and larger frogs were captured more commonly in the wet seasons (Figure 8). This might suggest that the greater abundance observed in the dry season might be marked by an explosion of juveniles dispersing into the landscape after the breeding season.

Hyla squirella was more abundant than *H. cinerea* during the study, and both species were found in all the sampled landscapes throughout the sampling period. Both these species are of similar shape, sizes and colors, and so I do not believe our observations of relative abundance are strongly affected by differences in detectability.

In an attempt to see if these two very similar, closely related species differ in the way they utilize their environment, I focused on the patch habitat which, given that its similar vegetation structure throughout both landscapes. Although the difference was not as marked in cypress prairie, in general, *H. squirella* was found perched higher than *H. cinerea* in patches. From another perspective, each species perched at similar heights independently of what landscape it was found in, supporting the concept that the vegetation structure and environmental parameters of patches do not differ greatly between landscape types. When pooled together, *H. squirella* shows to be perched overall higher than *H. cinerea*.

The species used the patch habitat somewhat differently. Although, contrary to my expectations, both species were found on the same perch substrates, but they used them in different proportions. *Hyla cinerea* is generally associated with permanent bodies of water (Leips and Travis 1994, Gunzburger 2007); whereas *H. squirella* is known to be more of a generalist in terms of habitat use (Lannoo 2005). *Hyla squirella* individuals also use vegetation that surrounds permanent bodies of water, but they are also found in woodlands and grasslands (Redmer and Brandon 2005). Goin (1958) noted that, where both species were found, *H. squirella* was generally found perched higher, in the canopy, than *H. cinerea*, found in greater predominance on aquatic vegetation (sawgrass, alligator flag) and closer to water. This might explain why, along a vertical spatial gradient I found *H. squirella* perched higher up on vegetation more frequently than *H. cinerea*. However, these differences in habitat use inside the domes might also suggest that what actually is occurring is that *H. cinerea*, the species generally found to be relatively bigger of both (Lannoo 2005), seems to be using, by where we find the vegetation they are predominantly perched on, what seems to be on vegetation in the deepest part of the domes, the center. The center of domes, by definition are the furthest part from any edge, therefore further from any threat edges may bring, and in particular *H. cinerea* is closer to the water than is *H. squirella*.

CONCLUSION

In this study I found that the matrix has an influence in the relative abundance of patch communities. Overall relative abundance seemed to be determined by matrix characteristic whereas seasonal fluctuations seemed to be a consequence of hydroperiod.

Hyla cinerea and *H. squirella* seemed to partition their common space along a vertical gradient with some difference in the proportions they used different vegetation to perch on. Although this study can not fully explain why the differences in patterns in abundace and habitat use took place, it contributes to show that difference in matrix characteristics, whichever specifically these may be, do have an effect on patterns of abundance of amphibians in patchy landscapes; and it also contributes to confirm there are differences, niche partitioning between these two similar, closely related frogs that inhabit the same landscape.

Studying amphibian communities in patchy landscapes contributes to conservation efforts because naturally patchy landscapes serve as a natural analogue of artificially fragmented landscapes (Ricketts 2001, Haynes and Cronin 2003, Kupfer et al. 2006, Watling et al. 2010). If we better understand the dynamics and factors shaping communities in these natural landscapes then we can make better decisions when it comes to choosing areas or communities to conserve and how to do so. In addition, little is known about these two species, and particularly in the BCNP; this thesis contributes to fill this gap in the scientific literature.

Also, the Greater Everglades System is an ecosystem of unique value both national and internationally. Named a World Heritage Site by the UNESCO, it is protected nationally by federal laws and internationally by treaties (e.g., the RAMSAR Convention). Wetlands in general provide key ecosystem services such as serving as buffers from storms, contributing to water purification and serving as nursery to many animal and plant species (www.unesco.org). The Everglades is one of the biggest wetlands in the country and is unique in North America for featuring both temperate and subtropical biodiversity

(Dovell 1947). It originally covered millions of acres but has since been reduced to half of its original extension. The urge of humans to populate these unused lands resulted in channeling of the “river of grass” to drain water and provide a place for agriculture and urbanization. Such modification of water flow brought not only a reduction in area but also incapacity to sustain such vast forms of life as it originally did (Lodge 2005). In light of the ongoing CERP, this thesis serves as information on pre-restoration conditions as to be able to later assess post-restoration success.

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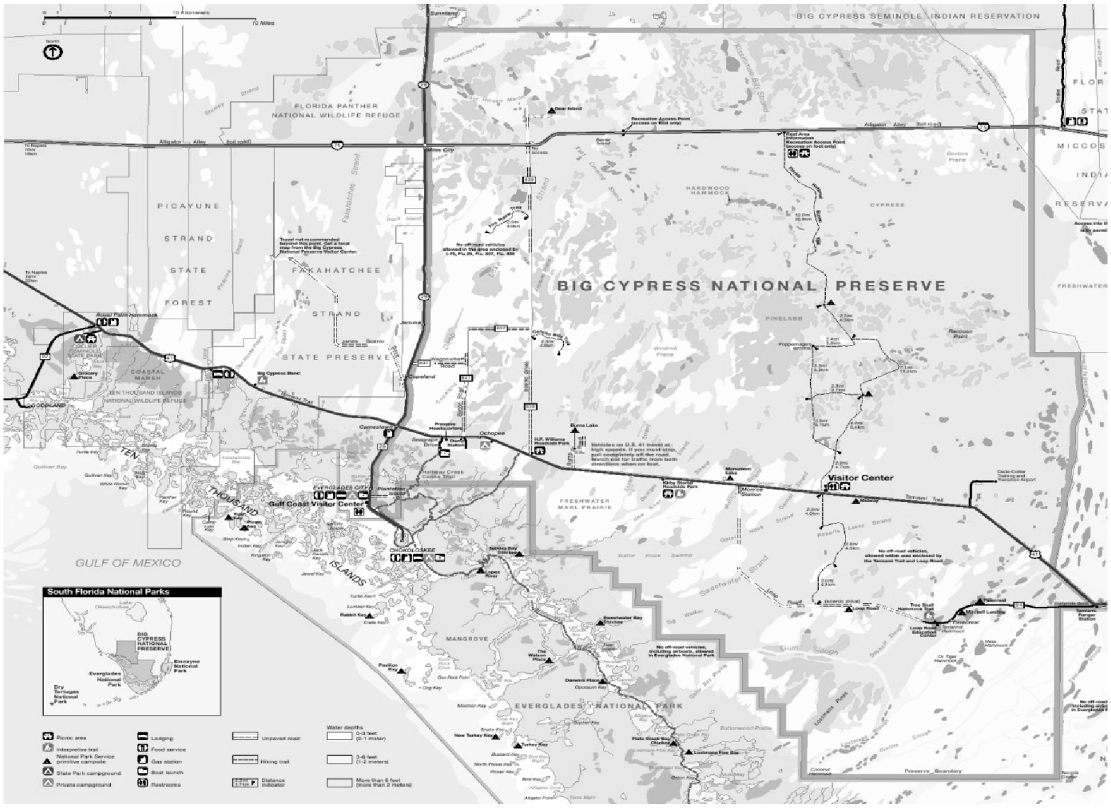


Figure 1. Map of Big Cypress National Preserve.
(http://www.nps.gov/bicy/planyourvisit/maps.htm).

A

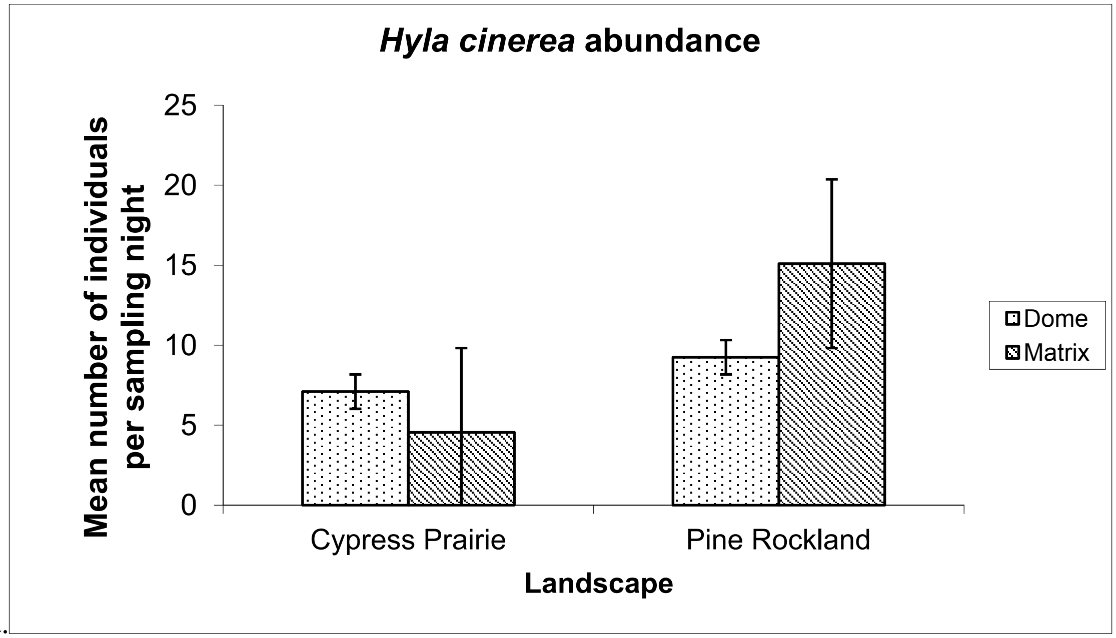
B

Figure 2. (A) *Hyla cinerea* distribution. (B) *Hyla squirella* distribution (from Conant and Collins 1991).

A.

B.

Figure 3. Selected patches at Raccoon Point, BCNP (A) in Pine Rockland. (B) in Cypress Prairie (Google Earth image).



a.

b.

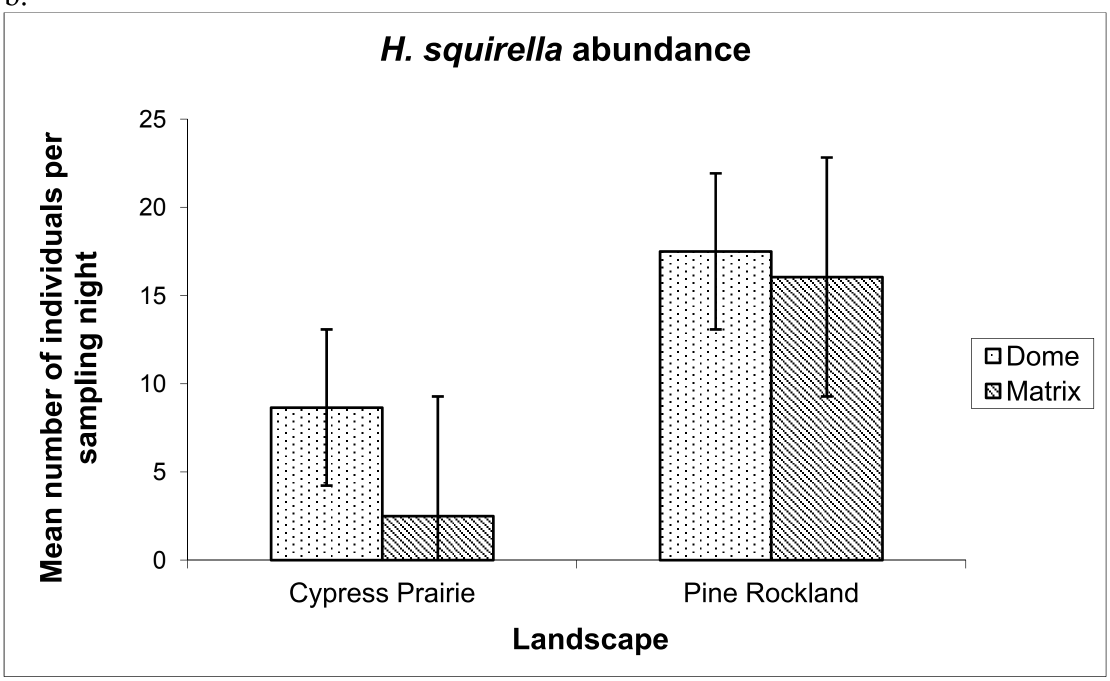
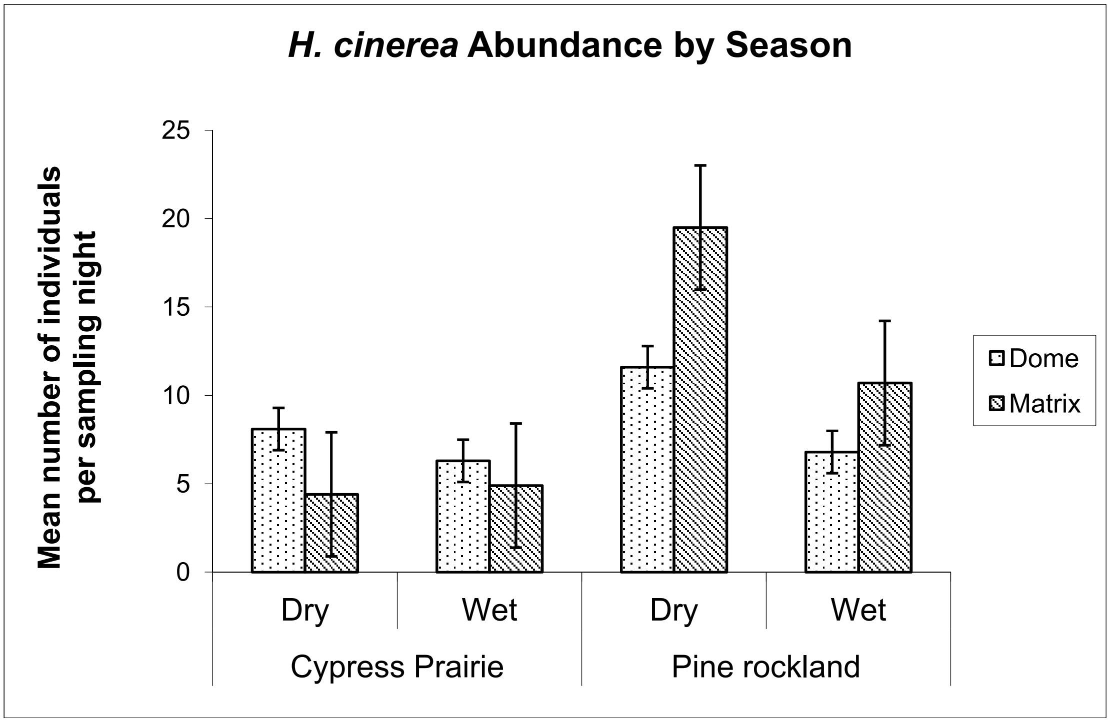


Figure 4. (a) Mean number of *H. cinerea* per landscape type, (b) Mean number of *H. squirella* per landscape type.

a.



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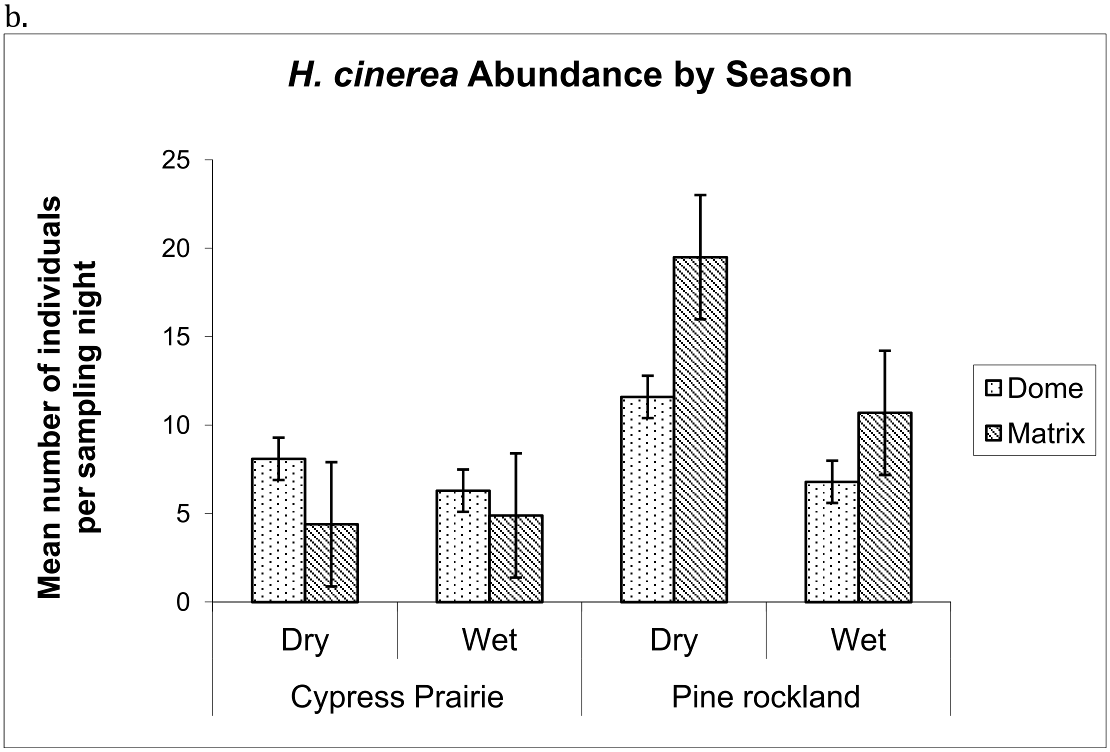


Figure 5. (a) Mean number of *H. cinerea* per landscape type in the dry and wet seasons, (b) Mean number of *H. squirella* per landscape type in the dry and wet seasons.

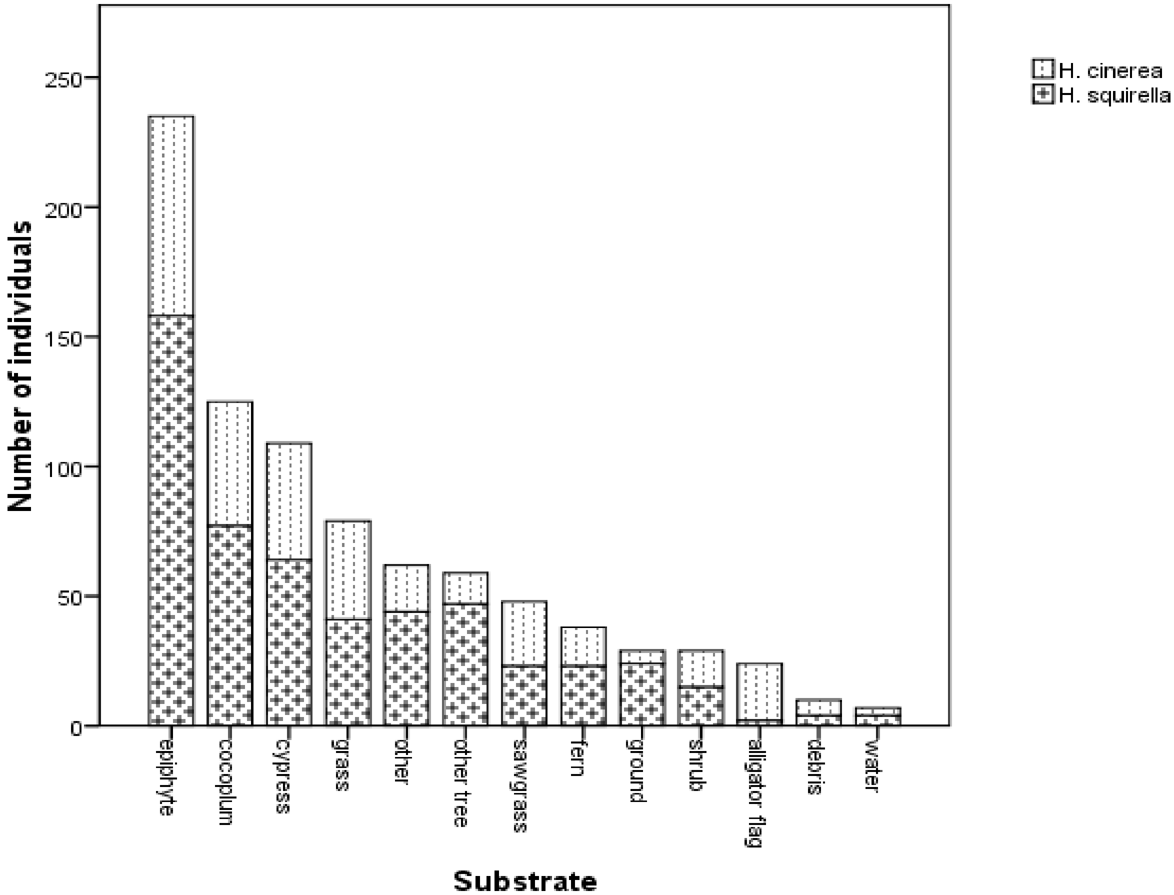


Figure 6. Number of individual frogs per substrate type.

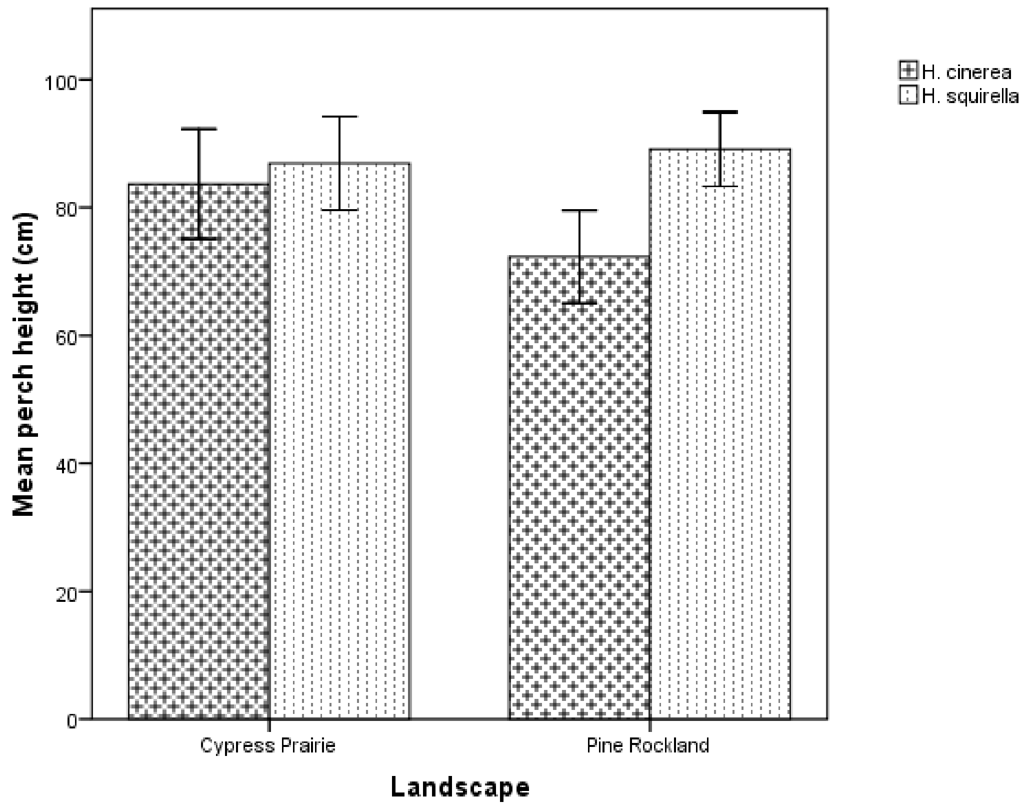
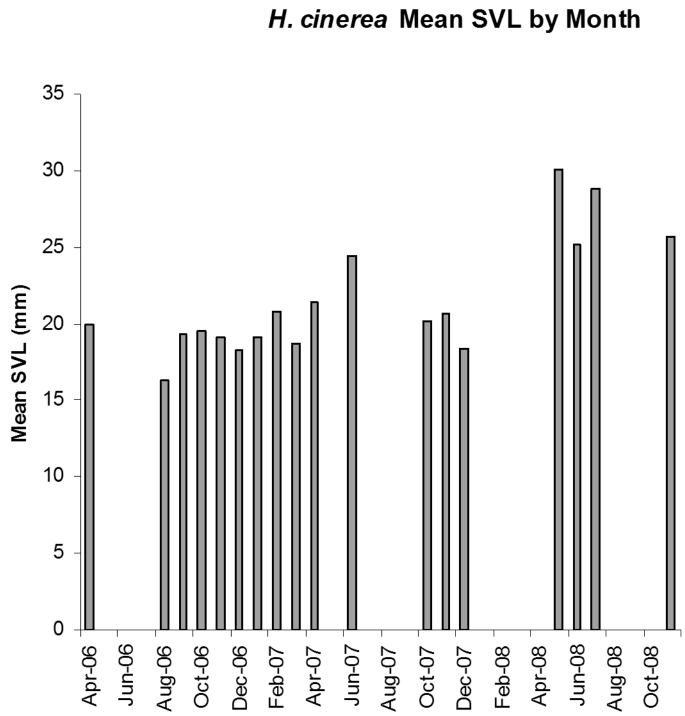


Figure 7. Mean perch height per species in different landscapes.

a.



b.

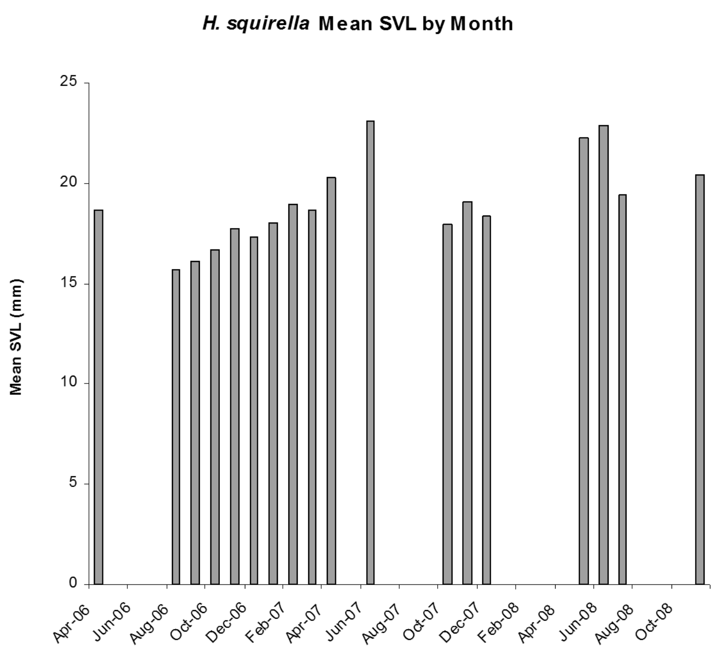


Figure 8. (a) Mean size (SVL) for *H. cinerea* per month, (b) Mean size (SVL) for *H. squirella* per month.

	2006	2007	2008
January		X	
Februaruy		X	
March		X	
April	X	X	
May	X		X
June	X	X	X
July	X		X
August	X		
September	X		
October	X	X	
November	X	X	X
December	X	X	

Table 1. Sampling periods.

a. *Hyla cinerea*

	Pine Rockland	Cypress Prairie	Overall
Dome	9.25 ± 0.519	7.1 ± 0.321	8.175 ± 0.313
Matrix	15.1 ± 0.662	4.55 ± 0.19	9.825 ± 0.384
Overall	12.175 ± 0.421	5.825 ± 0.196	

b. *Hyla squirella*

	Pine Rockland	Cypress Prairie	Overall
Dome	17.5 ± 0.519	8.65 ± 0.321	13.075 ± 0.313
Matrix	16.05 ± 0.662	2.5 ± 0.19	9.275 ± 0.384
Overall	16.775 ± 0.421	5.575 ± 0.196	

Table 2. (a) Mean number of *H. cinerea* frogs per landscape type per sampling night; (b) Mean number of *H. squirella* frogs per landscape type per sampling night.

		Substrate													Total
		A. flag	Debris	Epiphyte	Cocoplum	Cypress	Fern	Other Tree	Shrub	Grass	Sawgrass	Ground	Water	Other	
Hyla cinerea	Count	22	6	77	48	45	15	12	14	38	25	5	3	18	328
	% within species	6.7	1.8	23.5	14.6	13.7	4.6	3.7	4.3	11.6	7.6	1.5	0.9	5.5	100
	% within substrate	91.7	60.0	32.8	38.4	41.3	39.5	20.3	48.3	48.1	52.1	17.2	42.9	29.0	
Hyla squirella	Count	2	4	158	77	64	23	47	15	41	23	24	4	44	526
	% within species	0.4	0.8	30.0	14.6	12.2	4.4	8.9	2.9	7.8	4.4	4.6	0.8	8.4	100
	% within substrate	8.3	40.0	67.2	61.6	58.7	60.5	79.7	51.7	51.9	47.9	82.8	57.1	71.0	
Total	Count	24	10	235	125	109	38	59	29	79	48	29	7	62	854
	% within substrate	100	100	100	100	100	100	100	100	100	100	100	100	100	100

Table 3. Substrate use per species