**Acoustical Analysis of Anuran Density and Diversity at the Firestone Center for Restoration Ecology in Barú, Costa Rica**

Juliet Shih
Advisor: Donald McFarlane
Joint Science Department
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## Abstract

Amphibians represent a "canary in the coal mine," as such the diversity and abundance of amphibians is a good assessment of ecosystem health. Pitzer College's Firestone Center for Restoration Ecology (FCRE) in Barú, Costa Rica, contains mostly recovering rainforest. To monitor its recovery progress, the anuran diversity and density was investigated in 2008, continuing the amphibian population and diversity survey begun in 2006. The four man-made ponds of the FCRE property have become highly populated areas for amphibians. The population density of species found at each pond was determined using acoustical analysis. The species richness of each pond was also investigated. At each pond, four nights of recordings were made. On each night, the Song Scope Froglogger device was set to record for two minutes every hour, from 6PM to 4AM. Each recording was analyzed using Window's Media Player to listen and count the number of mating calls heard. The four species compared across the four ponds were *Agalychnis callidryas*, *Hyla ebraccata*, *Eleutherodactylus diastema*, and *Leptodactylus pentadactylus*. There were significant differences in populations of *A. callidryas*, *H. ebraccata*, and *E. diastema* across all ponds. Basilisk and Frog Pond shared a common dominant calling species (*E. diastema*) and Duck and Mudd pond shared a common dominant calling species (*H. ebraccata*). The species richness of each pond also varied greatly.

## Introduction

As a "canary in the coal mine" species, monitoring of amphibian populations and diversity can serve as an indicator of ecosystem health. Currently, amphibian species worldwide are in drastic decline. Scientists believe a number of contributing factors causing this modern day extinction include a mix of ecologically familiar and unfamiliar elements. Some relatively new factors include climate change and a deadly pathogen in the form of a chytrid fungus. The direct effect of climate change on global anuran populations is not certain, but changes in precipitation patterns are projected to diminish population ranges for many anuran species located in the tropics (Carey and Alexander 2003). The effect of the chytrid fungus on amphibian populations is obvious and devastating—the fungus parasitizes the skin of its semi-

aquatic hosts and impedes the respiratory pathways, resulting in suffocation of the amphibian (Berger *et al.* 1998). The more familiar ecological challenges affecting worldwide amphibian populations include habitat destruction and pollution. The continued decrease in available habitat, in addition to pollution, has been associated with reduced fitness and range of populations (Davidson *et al.* 2002). Habitat restoration efforts in Costa Rica have demonstrated that rainforest recovery can be fairly quick and successful. At the Firestone Center for Restoration Ecology (FCRE), located in southwestern Costa Rica, many tropical species that disappeared with the original clearing of rainforest have now returned, including many amphibian species.

In the 1950s-1960s, the FCRE 60 hectare property was cleared of its lowland moist forest and used primarily for cattle farming (FCRE website). Cattle farming ceased in the 1970s and the property was abandoned (FCRE website). Restoration began in the 1990s after Diane Firestone acquired the property (FCRE website). Today, the property consists of primary and secondary growth lowland moist forest, riparian woodland, banana trees, and bamboo forest. The bamboo has proven invasive and is currently controlled by harvesting. Despite this, both the bamboo and banana trees have created new niches for species found at the FCRE. *Odocoileus virginianus* (White-tailed deer) have been seen in the bamboo and *Dendrobates granuliferus* (Granular poison dart frog) populations in the banana trees have been reported at extraordinarily high levels, possibly indicating a healthy population (Cruz de Hoyos and Maanen, 2008).

To assess the ecosystem health of the FCRE property a survey of amphibian diversity and population densities has been ongoing since 2006. This continuing survey allows for a comparison between the species richness of amphibians on the FCRE reserve and that of the neighboring rainforest reserve, Hacienda Barú. The Hacienda Barú reserve consists of primary

growth rainforest and has not been subjected to heavy disturbance, unlike the FCRE. Although Hacienda Baru, at 330 hectares, is larger than the FCRE and would therefore be expected to support greater diversity, the species richness of amphibians on the Hacienda Barú reserve is two fold greater than that found on the FCRE reserve (FCRE Biodiversity: Amphibians, 2007). Using acoustical recording and analysis, amphibian populations at four ponds on the FCRE property were estimated and compared. The four ponds—Duck, Basilisk, Frog, and Mudd Pond—were also compared for differences in species richness.

**Methods and Materials**

Research on anuran populations and diversity was conducted on the FCRE property at four ponds: Duck, Basilisk, Frog, and Mudd Pond. The vegetation within and surrounding the ponds along with the size of each pond were varied (Table 1). Duck Pond was located in a continually disturbed region of the property, near the Access Road and bamboo plantation, and was well isolated from the other ponds. Basilisk Pond was near bamboo plantation as well as abandoned pastureland and is connected to Frog pond via a small stream. Mudd pond was located at a higher elevation from Basilisk, surrounded by bamboo plantation, and fairly isolated.

Amphibian mating calls were recorded on 16 different nights using a SongScope Froglogger. Two-minute recordings were made every hour, between the hours of 6PM to 4AM. Four recordings were taken at each of the four ponds. The average number of calls per minute was used as an indirect measure of population density.

Significant variations in call frequency between amphibian species made interspecies population density comparisons impossible. Instead, the call frequency of a species at a particular pond was compared to the call frequency of the same species found at another pond. There were four species found at all four ponds: *Agalychnis callidryas* (Red-eyed treefrog), *Hyla*

*ebraccata* (Hourglass treefrog), *Eleutherodactylus diastema* (Tink frog), and *Leptodactylus pentadactylus* (Smoky Jungle frog). The species richness of amphibians found at each pond was recorded.

**Table 1.** Study sites of anuran density and diversity at the FCRE.

| Pond | Relative Size | Isolated (Yes/No) | Aquatic Vegetation Abundance | Surroundings |
|---|---|---|---|---|
| Duck | Largest | Yes | Abundant | Bamboo, Banana Trees, Access Road |
| Basilisk | 2nd Largest | No | Abundant | Bamboo, Pastureland |
| Frog | 3rd Largest | No | Sparse | Bamboo, 2° Growth forest, cleared land |
| Mudd | Smallest | Yes | Sparse | Bamboo |

**Results**

Populations of *A. callidryas* were significantly different across all four ponds ($F = 5.77$, $df = 3$, $p = 0.0008$). Populations of *A. callidryas* at Duck Pond were significantly greater than that found at Frog and Mudd Pond (Tukey HSD, $p < 0.05$). Populations of *H. ebraccata* were significantly different across all four ponds ($F = 114.11$, $df = 3$, $p < 0.0001$). The population of *H. ebraccata* at Duck Pond was two and a half times greater than the population found at Mudd Pond, nearly three times greater than that found at Basilisk Pond, and 100 times greater than that found at Frog Pond (Fig. 1). There was also a significant difference in populations of *E. diastema* across all four ponds ($F = 19.47$, $df = 3$, $p < 0.0001$). Populations of *E. diastema* at Basilisk Pond were approximately eight times greater than that found at Duck Pond and three times greater than that found at Mudd Pond (Fig. 1). There was no significant difference in population densities of *L. pentadactylus* across all four ponds ($F = 2.11$, $df = 3$, $p = 0.0994$).

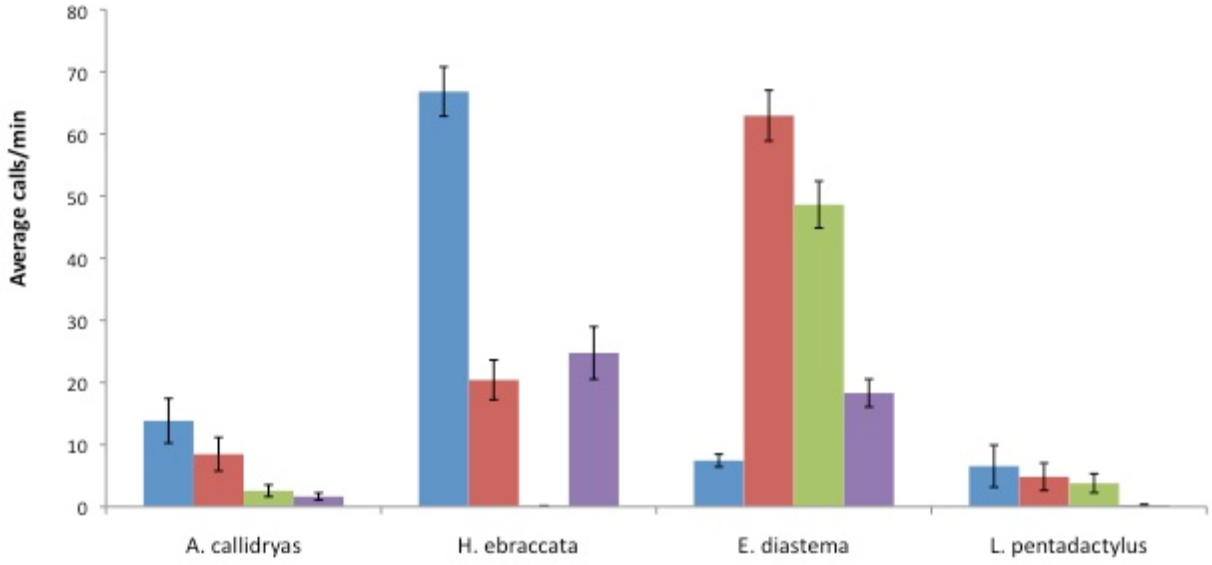


**Figure 1.** Comparison of FCRE ponds from 2008 study using the average calls per minute of four amphibian species. (Mean ± SE, n = 88, n = 44* = Duck Pond, = Basilisk Pond*, = Frog Pond, = Mudd Pond*)

The species richness varied across the ponds (Table 2). Duck Pond and Basilisk Pond were of the two largest ponds on the FCRE property and had the same number of species (Table 2). Frog Pond had the highest number of species (Table 2). This pond was the third largest pond on the property and, in comparison to the other ponds, was surrounded by the most diverse terrain (Table 1). The second highest species richness was found at the smallest pond, Mudd Pond (Table 2).

**Table 2.** Species richness and relative size of ponds on the FCRE property.

| Pond | Relative Size | Species Richness (S) |
|---|---|---|
| Duck | Largest | 7 |
| Basilisk | 2nd Largest | 7 |
| Frog | 3rd Largest | 10 |
| Mudd | Smallest | 9 |

**Discussion**

There were significant differences in the population densities of the four shared amphibian species across the four ponds on the FCRE property. The four ponds seemed to have similar population densities of one species, *L. pentadactylus*. Populations of *A. callidyras* were also fairly similar, but statistical results showed significant differences. *H. ebraccata* and *E. diastema* populations varied significantly across the four ponds but there does not seem to be a clear population trend.

Only one species, *L. pentadactylus*, appeared to have a consistent calling frequency regardless of pond location, indicating that the populations across all four ponds were fairly similar. *L. pentadactylus* are large carnivorous amphibians and are not directly dependent on a permanent body of water for reproduction or feeding (Savage 2002). Being carnivorous, the level of energy necessary to function depends indirectly on the size of its habitat and directly on the availability of prey. Though not significantly different from the other ponds, the population of *L. pentadactylus* at Duck Pond was greatest. Duck Pond, being the largest on the reserve, may have been able to support larger populations of prey in comparison to the smaller ponds, therefore producing enough prey items to support a larger population of *L. pentadactylus*.

The populations of *A. callidryas* and *H. ebraccata* were also highest at Duck Pond, possibly due to the abundance of both terrestrial and aquatic vegetation (Table 1). *A. callidryas* seek shelter in the canopy of trees during the day and descend to call in the early evening (Savage 2002). The population of *A. callidryas* may have found the abundance of banana trees near the pond as suitable habitat. From personal observation, the majority of observed *A. callidryas* were found on the trunks of banana trees as individuals descended in the early evening to begin calling. *H. ebraccata* were the most abundant species found at Duck Pond. Individuals

of this species were easily found calling from leaves of aquatic plants in the pond and extreme chorusing began shortly after nightfall.

There was some variation in species richness across the four ponds but the differences were not substantial. Duck and Basilisk Pond shared the same number of species (S =7). This may be due to similar abundances of aquatic vegetation. Duck Pond had high levels of aquatic grasses while Basilisk Pond was heavily invaded by introduced water hyacinths. Mudd Pond had the second highest number of species (S = 9) and Frog Pond had the highest (S = 10). It is interesting to note that the two smallest ponds had the highest number of species. At Mudd Pond, the populations of *A. callidryas* and *L. pentadactylus* were very low (Fig. 1). In addition, the populations of *H. ebraccata* and *E. diastema* at Mudd Pond were also comparatively low with respect to the other three ponds (Fig. 1). Frog Pond shared a similar pattern with Mudd Pond, with the exception of *E. diastema* (Fig. 1). The low population density of the four shared species across all of the ponds may be an indication of abiotic or biotic factors that keep one species from dominating all others. Frog Pond may be subjected to high disturbance—it is connected to Basilisk Pond by a stream and is surrounded by highly varying terrain (Table 1). Species from Basilisk may often be transported via stream during heavy rain and because of the various terrain, no one species can specialize to utilize every type of terrain. There may be high competition at Mudd Pond, due to its size, location, and lack of aquatic vegetation. Mudd Pond is well isolated and surrounded by bamboo. In several recordings, *D. granuliferus* were heard calling. The reproductive behavior of this species does not require a permanent body of water but was often observed near Mudd Pond, presumable calling from the bamboo. The lack of aquatic vegetation may force species at this pond to compete for shelter, food, or other resources.

The small size may limit the number of occupying species and, in combination with the lack of aquatic vegetation, may be increasing the level of competition.

Nearly all of the species found throughout the FCRE property in 2007 were found in 2008 (Appendix A). In 2008, 15 of the 17 species found in 2007 were seen. Missing from the 2008 list were *Agalychnis spurrelli* (Flying treefrog) and *Phrynohyas venulosa* (Pepper treefrog). A new species, *Eleutherodactylus vocator*, was discovered in a recording and identified by an anuran call specialist.

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**Appendix A**

2008 Species List

1. *Agalychnis callidryas* (Red-eyed treefrog)
2. *Bufo haematiticus* (Smooth-skinned toad)
3. *Bufo marinus* (Cane toad)
4. *Bufo melanochlorus* (Wet forest toad)
5. *Dendrobates auratus* (Green and black poison dart frog)
6. *Dendrobates granuliferus* (Granular poison dart frog)
7. *Eleutherodactylus bransfordii* (Bransford’s litter frog)
8. *Eleutherodactylus diastema* (Tink frog)
9. *Eleutherodactylus fitzingeri* (Fitzinger’s litter frog)
10. *Eleutherodactylus vocator*
11. *Hypsiboas rosenbergi* (Gladiator tree frog)
12. *Hyla ebraccata* (Hourglass treefrog)
13. *Hyla microcephala* (Small-headed treefrog)
14. *Leptodactylus pentadactylus* (Smoky jungle frog)
15. *Scinax elaeochroa* (Green-boned treefrog)
16. *Smilisca phaeota* (Masked treefrog)