Territorial Mating Behaviors of the Male Green Frog (*Rana clamitans*) in Lake and Beaver Pond Habitats

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Abstract

In order to test whether male green frogs at UNDERC exhibit territorial behavior, I recorded male green frog size and spatial distribution in a roadside beaver pond and in a cove of Roach Lake. In grids of 30m x 10m for both sites, I studied these populations over a four day period and spatially mapped their positions in a global positioning program. I also recorded the number of advertisement calls per hour at both sites in the morning, afternoon, and night for a four day period and conducted a vegetation survey of both sites. I captured 30 males at the beaver pond (0.2 frog/m^2) and 21 males at Roach Lake (0.14 frog/m^2). I found no patterns in male size and distance from other males, but did discover a significantly higher average call rate ($p=0.019$) at the beaver pond, which also contained significantly larger males ($p=0.001$) than those at Roach Lake. Call rate was significantly higher at night than during the morning and afternoon at both the beaver pond ($p<0.001$) and Roach Lake ($p=0.008$). Additionally, in Roach Lake more males were found in areas with a higher percent cover of emergent vegetation ($p=0.003$), suggesting that frogs spatially distribute themselves according to vegetative microhabitat features. Because the beaver pond supported a population of mating male green frogs with a significantly greater snout-vent length and significantly higher call volume, this study suggests that frog density may influence call frequency.

Introduction

The green frog, *Rana clamitans*, was one of the first amphibian species to which territoriality was ever ascribed (Martof 1953). The mating strategy of the green frog differs markedly from most amphibian species who exhibit "irruptive" spring mating patterns in which they will assemble in leks for one to two weeks and breed at a very high rate, calling mostly at night. In contrast, the green frog has a prolonged mating season, often lasting from June to August, and calls virtually 24 hours a day. Generally, male green frogs leave their non-reproductive stream habitat and congregate in ponds, lakes, and slow moving stream areas during this mating period; females remain in the non-reproductive habitats and leave only for one to 30 days to mate before returning to the non-reproductive habitat. Egg clusters are deposited along the surface of the water in emergent or floating vegetation and hatch in three to five days. Martof (1956) found that the green frog mates more actively in warm, rainy weather than in dry or cold weather.

Since the mating behaviors of the green frog was first described in the 1950s, research has been conducted on the orienting mechanisms of the green frog (Oldham 1967), territoriality in experimental ponds (Wells 1977), size dimorphism and reproductive success (Woolbright 1983), and distribution and abundance of the species (Hecnar and M'Closkey 1997). Oldham(1967) found that male green frogs removed from their mating territories showed a marked preference to return to this site, and males tended to maintain their same territory throughout the mating season and often from year to year. However, Wells (1977) noted that male green frogs in experimental pools normally occupied more than one territory during the mating season but that large males were more likely to maintain a territory than small males. Woolbright (1983) found that larger males were often able to maintain a larger territory and experience a greater reproductive success in prolonged breeders such as the green frog but that size is limited due to the energetic costs of advertising calls and limiting food intake. One of the more recent and wide-spread studies of green frog populations found that green frogs showed no trend in abundance in 47% of their study sites but that small scale extinctions were most likely in habitats which support only a small number (<10 adults per pond) of green frogs (Hecnar and M'Closkey 1997).

Although green frog populations have been extensively documented and territoriality has been observed in experimental settings, little research has focused on documenting territorial behavior in their natural mating territories. Additionally, no study has focused on territory preference of males in terms of habitat type or available vegetation. The purpose of this study was to map the spatial distributions of male green frogs in two different mating habitats, a cove of Roach Lake and a roadside beaver pond at UNDERC (University of Notre Dame Environment Research Center) in Gogebic Co., Michigan and Vilas Co., Wisconsin, and to look for patterns in male size and distribution, vegetation relative abundance, and call rate differences within and between sites. I hypothesized that male green frogs will display territorial behavior at both of these sites. Therefore, I predicted that larger males would maintain a larger distance between themselves and the closest male and that call rate would be greater in sites with larger males. Additionally, I expected to find males occupying territories in areas with a larger percentage of emergent and floating vegetation. Because male size is limited by the energetic costs of advertisement calls and maintaining a territory, I expected to capture larger males in the lake habitat. My reasoning was that, although I studied equal areas at both sites, male green frogs in the beaver pond would be limited by available shoreline, whereas the shoreline of Roach Lake provides additional suitable mating habitats for frogs in surrounding coves; therefore, if density were to increase at the beaver pond, males would have fewer territory options and would have to maintain their positions through territorial behavior.

Methods

Based on past herpetology surveys of the UNDERC property, I selected two sites with high densities of green frog populations, which I believed would be most likely to induce competitive behavior. I mapped male green frog positions in two different mating habitats, a cove of Roach Lake and a beaver pond, from 1300 h-1600 h CDT over a four day period (June 27-June 30, 2006). I captured adult male green frogs, flagged their positions, recorded their snout-vent lengths and cloacal temperatures, and then released them at the point of capture at the end of each sampling period. At the end of the four day mapping period, I used GPS (Datum UTM NAD27 Zone 16N) recordings and transferred them to a layer in ArcView 3.3 (HCL Technologies Limited, New Dehli, India) to map their positions in each habitat and determine distances between males. I used linear regression to test for a significant relationship between male snout-vent length and distance to the closest male. I also used a t-test to test for a significant difference in male green frog size between my two sites.

From July 17-July 20, 2006, I recorded call frequency at each site. I recorded the number of mating calls per hour at each site from ca. 0900-1000 h, ca. 1300-1400 h, and ca. 2100-2200 h. I used a two-way ANOVA to find any significant differences in call rate between sites or between different times of day.

I also performed a vegetation survey of each site using 1m x 1m plots at 30 random locations along the shoreline of each site; I estimated percent cover of emergent, submerged, and floating vegetation as well as algae and woody material. I used a step-wise linear regression to find significant relationships between number of frogs per plot and percent cover of the different vegetation types.

Results

After plotting male positions in ArcView, I determined that males tend to stay close to the shore and distribute themselves fairly evenly along the shoreline; however males do not always maintain large distances from other males; occasionally two males will be less than 0.5 m apart (Figures 1 and 2). In order to determine whether large males maintain a larger distance between themselves and other males, I used ArcView to determine each male's distance to the nearest male. I ran a linear regression and found that no significant relationship exists between male size, measured in snout-vent length, and distance to the nearest male at either the beaver pond (R^2=0.002, p=0.834) or Roach Lake (R^2=0.040, p=0.387). However, I ran a t-test to compare male snout-vent lengths between the two sites and found that males at the beaver pond (N=30 males) were significantly larger than males at Roach Lake (N=21 males, t=13.093, p=0.001). The average male snout-vent length at Roach Lake was 7.6 cm (standard error=0.238), whereas the average male snout-vent length at the beaver pond was 6.2 cm (standard error=0.284).

A step-wise linear regression to test for a relationship between percent cover of each type of vegetation and the number of frogs occupying the plots containing that vegetation found only a significant relationship between number of male frogs and percent cover of emergent vegetation and algae (Table 1). A linear regression showed a higher number of frogs in areas with a higher percent cover of emergent vegetation at Roach Lake (R^2=0.270, p=0.003) but not at the beaver pond (R^2=0.054, p=0.217). Though the step-wise regression showed a significant relationship between number of male frogs and percent cover of algae, the beaver pond contained no algae at all and a linear regression of number of male frogs and percent cover of algae for Roach Lake revealed no significant relationship (R^2=0.068, p=0.164). Also, no significant relationship existed for the number of male green frogs and submerged, floating, or woody vegetation (Table 1).

I ran a two-way ANOVA to determine whether there was a significant difference between sites and times of day with respect to number of male advertisement calls per hour. Males called significantly more times per hour at the beaver pond than at Roach lake over all four nights (F=6.620, df=1, p=0.019), and males called significantly more at night than they did during the morning or afternoon across both sites (F=28.726, df=2, p<0.001). I grouped my data by site, ran a one-way ANOVA, and determined that males call significantly more frequently at night than in the morning and afternoon at both the beaver pond (F=20.196, df=2, p<0.001) and Roach Lake (F=8.619, df=2, p=0.008, Figure 3). Additionally, a significant relationship existed between ambient temperature and call rate in which males called more at lower ambient temperatures (R^2=0.276, p=0.008).

Discussion

The positional data I collected at both the beaver pond and Roach Lake do not support my hypothesis that male green frogs would exhibit territorial behavior. If they were behaving territorially, it would follow that larger male green frogs would maintain larger distances between themselves and other males than smaller males would, but there was no significant distance between male size and distance from the closest male. However, the beaver pond site, which had significantly larger males than Roach Lake, also had a significantly higher average call rate per hour than Roach Lake. If the male green frogs are exhibiting territorial behavior, this difference would make sense because areas with larger males would exert more pressure on males to compete for mates. Because the size of the beaver pond is relatively more restricted than Roach Lake, the upper threshold for territory size would be smaller than in a lake; therefore, out competing another male vocally would be more efficient than out competing another male spatially.

Contrary to my prediction that a lake habitat would contain larger males than a beaver pond habitat, my results indicate that the beaver pond I sampled supported a male green frog population with a significantly higher snout-vent length than Roach Lake males. This result seems to be counterintuitive, but my vegetation surveys may explain this effect. In Roach Lake, there was a significant, positive relationship between percent cover of emergent vegetation and the number of male green frogs found in a square meter area. However, in the beaver pond there is no significant relationship between male green frog density and any type of vegetation. This may indicate that despite the larger size of Roach Lake, the beaver pond may have a larger number of suitable territories available for male green frogs. Therefore, whereas vegetation type would be a limiting factor in Roach Lake, it would be less of a factor in the beaver pond. The beaver pond would then be capable of accommodating a larger population of male green frogs, both in size and number. Indeed, beaver ponds are documented to increase the flora diversity and nutrient levels of aquatic systems, which can be beneficial to many aquatic species, including amphibians (Naiman et al. 1988).

My results also indicate that green frogs increase their call rate significantly at night time as opposed to morning and afternoon. Male populations at both Roach Lake and the beaver pond called more frequently at night. Since advertisement calls require a significant amount of metabolic energy and green frogs call 24 hours a day for three months or longer (Woolbright 1983), it would make sense that they would decrease their call rate for some portion of that time in order to conserve energy. However, why they call more at night is uncertain. Martof (1956) indicated that green frogs prefer warm temperatures for mating, yet my results show a significant relationship between a higher call rate and cooler temperatures; this relationship probably exists because most calling was occurring at night when temperatures are cooler. The most obvious explanation for calling more at night would be that it decreases the likelihood of being targeted by predators than calling during the day. Martof (1956) found that the most common predators of adult green frogs are garter snakes and crows; since calling and being readily visible during the day would increase the likelihood of mortality, it is conceivable that increasing call rate at night increases the likelihood of finding a mate and decreases the likelihood of being preyed upon. A study which also considers sources of frog mortality at these sites would be necessary to confirm this explanation.

Though the results of this study do not confirm territoriality of the green frog at these two sites, they also do not refute it. In order to enhance this study, I would recommend a follow-up project which would use a method of identifying individual frogs and tracking them over a period of several weeks to map their movement around or possibly between the experimental sites. Furthermore, a study which measures the call rates and sizes of individual males would provide further insight into how males balance the metabolic demands of growth and advertisement calls in response to intraspecific competition. I would also recommend a study which specifically focuses on beaver ponds in comparison to other forms of aquatic habitats and assesses whether my findings apply to other beaver ponds. If this is the case, efforts should be made to protect these habitats in order to maintain green frog populations. Replication of sites in each habitat type is necessary in future projects.

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Tables

Table 1: Results of step-wise regression, showing relationships between the number of frogs found in each 1m x 1m vegetation plot and percent cover of vegetation type per plot. Significant relationships are shown in bold.

Vegetation type	F	P
Emergent	**10.284**	**0.002**
Algae	**3.297**	**0.075**
Wood	0.000	0.982
Submerged	0.235	0.630
Floating	0.599	0.442

Figures

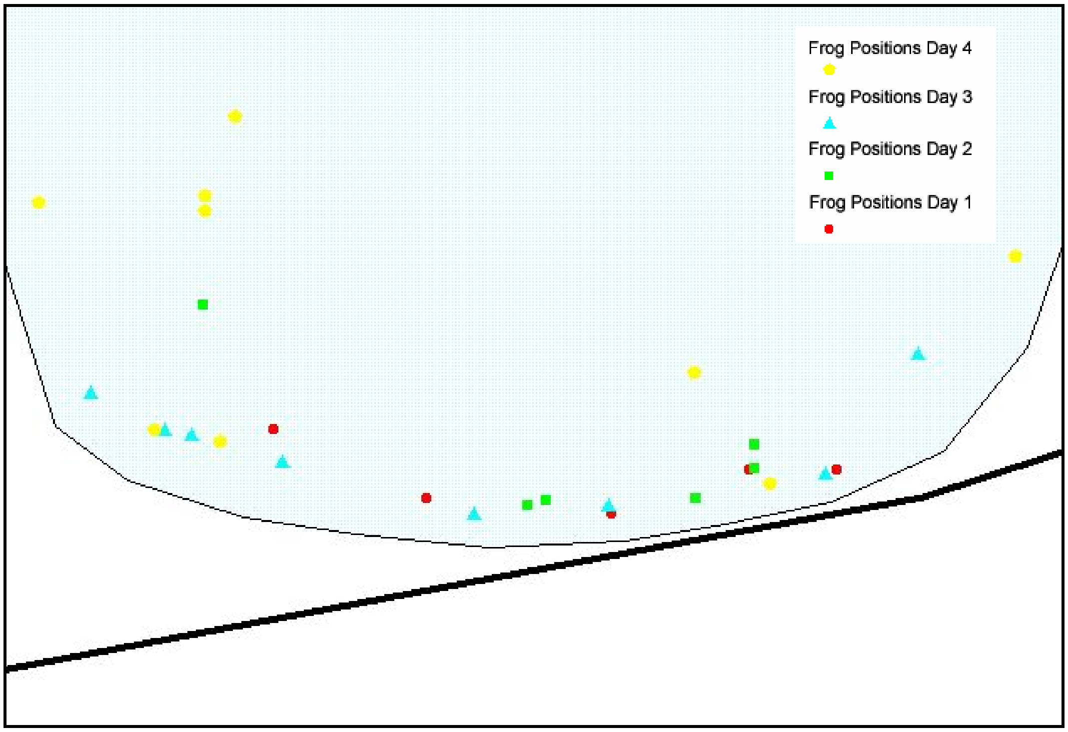

Figure 1: ArcView image of positions of male green frogs around the shoreline of the beaver pond over a four day period. The blue shaded area represents open water, and the dark black line represents a road.

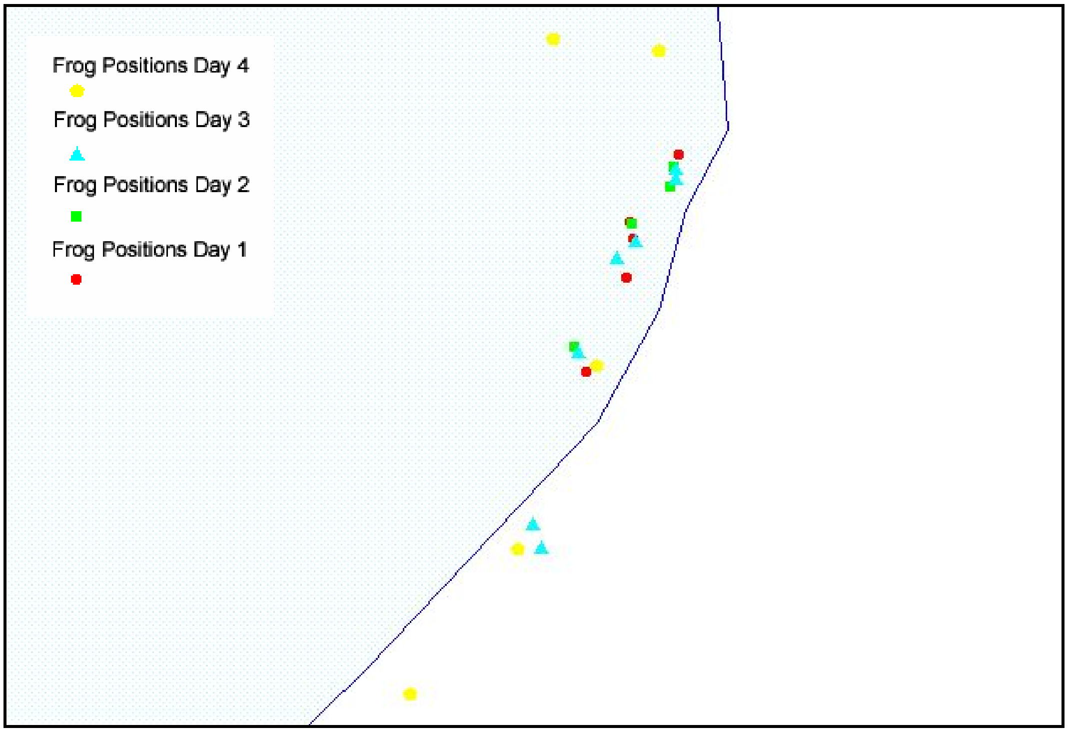

Figure 2: ArcView image of positions of male green frogs around the shoreline of a cove of Roach Lake over a four day period. The shaded blue area represents open water.

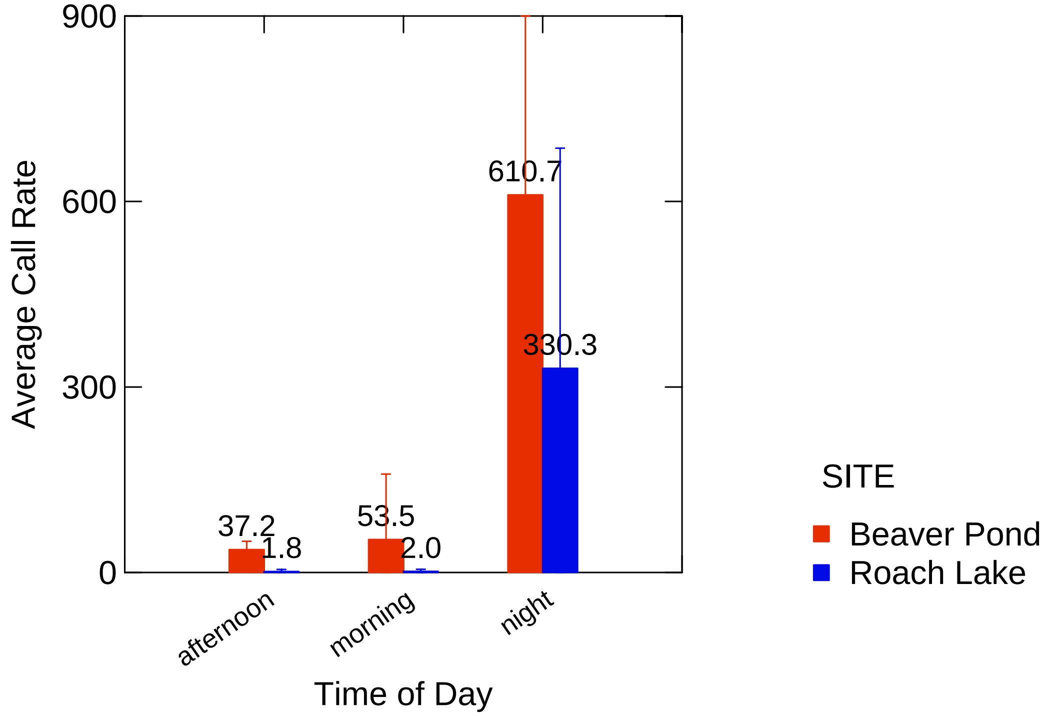

Figure 3: Males called significantly more times per hour at night than during the morning or afternoon at both the beaver pond (F=20.196, df=2, $p<0.001$) and Roach Lake (F=8.619, df=2, p=0.008). Averages are shown, and error bars show a 95% confidence interval.