

## DIURNAL CHORUSING IN NINE SPECIES OF NORTH AMERICAN ANURANS

MALCOLM L. MCCALLUM<sup>1</sup> AND JAMIE L. MCCALLUM<sup>2</sup>

<sup>1</sup>*Aquatic Resources Center, School of Agriculture & Applied Sciences, Cooperative Research and Extension, Langston University, P.O. Box 1730, Langston, Oklahoma 73050, USA,  
e-mail: malcolm.mccallum.tamut@gmail.com*

<sup>2</sup>*Northern Oklahoma College, Department of Biology and Agriculture, Tonkawa, Oklahoma 73702*

**ABSTRACT:** A year-long survey of diurnal frog calling behavior was conducted at the Red River Research and Education Park in Shreveport (Caddo Parish), Louisiana to investigate the prevalence of daytime breeding choruses in the species present at the park. We determined that 60% (9/15) of species known from the area participated in daytime breeding choruses. Four of these were new species reports for the behavior. One species was identified entirely based on a daytime chorus from outside the normal breeding season. Although we believe daytime chorusing is widespread in frogs, several species did not diurnally chorus during our study. Diurnal calling may be an important indicator of the peak breeding season for a species and it may also be a useful tool at times when nocturnal surveys are impossible.

*Key Words:* breeding chorus, diurnal calling behavior, frog calls, Anura, anurans, frogs, toads

### INTRODUCTION

Much research has focused on calling behavior in frogs (Gerhardt 1994), but these studies are typically performed at night. In fact, virtually all descriptions of anuran calling behavior are based on nocturnal surveys and observations. However, many species continue calling for mates throughout daytime hours (pers. obs.), despite the lack of attention to this behavior. Although there are mentions of diurnal breeding choruses in the literature (e.g., Mesoamerican Cane Toad (*Rhinella marina*) (Krakauer 1968; Meshaka 2011), the Coqui (*Eleutherodactylus coqui*) (Meshaka 2011), Greenhouse Frog (*Eleutherodactylus planirostris*) (Goin 1947; Meshaka et al. 2004), and the Cuban Treefrog (*Osteopilus septentrionalis*) (Meshaka 2001, 2011)), few studies specifically investigate the prevalence of diurnal breeding choruses in frogs. The only known study specifically approaching diurnal calling in North America was conducted at the U.S. Department of Energy's Savannah River Site in South Carolina and used automated recording systems to continuously record calling behavior (Bridges and Dorcas 2000). It found that Southern Cricket Frogs (*Acris gryllus*), American Bullfrogs (*Lithobates catesbeianus*), Green Frogs (*L. clamitans*) and Eastern Narrow-mouthed Toads (*Gastrophryne carolinensis*) regularly called during the day, albeit less frequently than during the night. Southern Leopard Frogs (*Lithobates sphenoccephalus*), Green Treefrogs (*Hyla cinerea*), Pinewoods Treefrogs (*H. femoris*), and Cope's Gray Treefrogs (*H. chrysoscelis*)

day-called sporadically, and Barking Treefrogs (*H. gratiosa*) did not call during the day. Further, Spring Peepers (*Pseudacris crucifer*) and Blanchard's Cricket Frogs (*Acris blanchardi*) oviposit during the day and night in New York (Wright 1914) and diurnally chorus early in the breeding season (Kenney and Stearns 2015).

Meshaka and Layne (2015) note diurnal observations of calling among several species in South Florida. Here, rainfall the previous night induced Oak Toads (*Anaxyrus quercicus*), Southern Toads (*Anaxyrus terrestris*), Squirrel Treefrogs (*Hyla squirella*), Southern Chorus Frogs (*Pseudacris nigrita*), Little Grass Frogs (*Pseudacris ocularis*), Eastern Narrow-mouthed Toads and Green Treefrogs to call during the day (Duellman and Schwartz 1958, Meshaka and Layne 2015). Male Squirrel Treefrogs appear to be fertile year-round in South Florida (Meshaka and Layne 2015). Eastern Narrow-mouthed Toads from south-central Florida are known to diurnally call in March (Meshaka and Layne 2015). Southern Cricket Frogs diurnally call throughout the year (Meshaka and Layne 2015). Groups of Pinewoods Treefrogs also sometimes call on sunny days in upland sites in Florida (Meshaka and Layne 2015), but are probably not breeding calls.

Eastern Narrow-mouthed Toads may also day-call in Georgia (Wright 1931), coastal Texas (Pope 1919), and the Grand Cayman Islands (Meshaka and Layne 2015). Pig Frogs (*Lithobates grylio*) and Florida Gopher Frogs (*Rana capita*) occasionally perform breeding calls during the day in Florida (Meshaka and Layne 2015). Reports of



Figure 1. Historical aerial imagery of the Red River Research and Education Park (Shreveport (Caddo Parish), Louisiana) in 2003-2004. Yellow markers indicate each of nine observation stations (Source: Google Earth). Labels are sampling sites pictured in Fig. 2.



Figure 2. Habitats at nine listening stations at the Red River Research and Education Park, Shreveport, Caddo Parish, Louisiana, during 2003-2004. Labels refer to sampling points in Fig. 1. (Photos by Jamie McCallum).

day-calling Pinewoods Tree Frogs also exist for Georgia (Wright 1931) and in the Carolinas (Martof et al. 1980). Of note, Dundee and Rossman (1989) reported large choruses of Eastern Spadefoots (*Scaphiopus holbrookii*) in Louisiana that were sometimes active during the day.

Most studies of frog calling ignore daylight hours, and many guidelines (e.g. North American Amphibian Monitoring Program (NAAMP), FrogWatch) recommend surveys in the early evening hours. There has been much discussion about the importance of natural history in the face of conservation needs (Bury 2006, McCallum and McCallum 2006), and diurnal chorusing data are certainly lacking. Herein, we provide observations demonstrating diurnal calling in multiple species of anurans.

#### MATERIALS AND METHODS

The study site was an oxbow lake and wetland at the Red River Research and Education Park (a.k.a. C. Bickham-Dickson Park) in Shreveport, Caddo Parish, Louisiana (Population ~ 400,000). This 249 ha urban wetland (Fig. 1) surrounded an oxbow lake that was connected by a small channel to the Red River during most of the year. During the winter, the Red River frequently inundated the park. The vegetation in the park was a mix of native and exotic species (MacRoberts et al. 2008).

We visited the Red River Watershed Research and Education Park between 1100 and 1300 hrs 249 times from 20 September 2003 through 4 January 2005, totaling 249 visits. Some stations could not be visited during floods. Each visit lasted 60–120 min. We drove the perimeter road with the windows down and stopped at nine watch stations (Fig. 1, 2). Whenever frogs were heard calling, we stopped, left the vehicle, listened quietly, then recorded the location and species heard. All sessions were recorded with a hand-held digital audio recorder for later review and verification. For the purpose of this study, isolated single calling males were excluded because these were more characteristic of a rain-induced call than calling for mates. We also recorded ambient temperature and wind speed using a Kestrel® hand-held weather unit and then noted any precipitation during each stop. We could not survey frog calling at night because of city ordinance, locking of the park gate outside of working hours, and a lack of funds for automated recorders. The minimum number of stops during each visit was one per each of the nine stations selected at the beginning of the study. Results were statistically analyzed with regressions using MiniTab 13.0.

#### RESULTS

Nine species of anurans called diurnally during our study (Table 1). Among those, only the American Toad (*Anaxyrus americanus*) had not been physically observed at the park or in the immediate surrounding area. The Pickerel Frog (*Lithobates palustris*) and Cope's Gray Treefrog were known from the surrounding area and were not previously observed at the site, but were detected via daytime choruses. The Green Treefrog, Gray Treefrog (*H. versicolor*), and Cajun Chorus Frog (*Pseudacris fouquettei*) were previously recorded at the park, but were not detected during our daily visits.

Based on our observations, diurnal and nocturnal chorusing strongly overlapped for Blanchard's Cricket Frog. For this species, diurnal calling surveys may be as useful as nocturnal ones. Six species had daytime detection windows that were shorter than the known nocturnal

choruses (Table 1). For example, Cope's Gray Tree Frog breeds from March – July but was only observed chorusing diurnally in October (Table 1). Surveys for these species would be more efficient if performed at night.

There was sufficient data to assess interactions among ambient temperature, wind speed and chorusing in five of the nine species observed calling diurnally (Table 2). Among these five species, only Blanchard's Cricket Frog responded to ambient temperature or wind speed ( $r^2 = 0.307$ ). Depending on the date, temperature and wind speed influenced whether this species diurnal chorused (Table 3).

#### DISCUSSION

Previous observations suggest that using a limited listening window in the evening may cause some species to go undetected (Bridges and Dorcas 2000). In fact, our data support this concern. Cope's Gray Treefrog was not previously known at the park; however, we detected diurnal choruses in the fall. This species would have gone undetected had we not surveyed the entire year. Whether fall diurnal chorusing was errant or typical behavior for the region is unknown. However, there have been observations of overwintering Cope's Gray Treefrog tadpoles in Shreveport, (McCallum and McCallum 2004) of a size suggesting fall oviposition. If this species breeds in the fall, its tadpoles would need to overwinter before metamorphosing.

Blanchard's Cricket Frog breeding choruses take place between March and October in the Arkansas Ozarks (McCallum 2003, Trauth et al. 2004). Females with large vitellogenic ova are present from April to August and males have sperm present throughout the year in most of Arkansas (McCallum et al. 2011). Day-calling is prominent from March to September in northwestern Louisiana. By September, females with yolked egg clutches are rare in Arkansas, and the population has largely turned over to young-of-the-year (McCallum 2003, McCallum et al. 2011). Considering the latitudinal differences between northwestern Louisiana and most of Arkansas, diurnal calling closely overlaps the presence of ripe females in the population. We pose that diurnal calling may indicate the peak breeding activity and potentially reflect testosterone levels in male frogs. However, more in-depth studies are needed to validate these two hypotheses.

Our study suggests that diurnal chorusing by anurans might be more widespread than previously known and that failure to consider this may result in undetected but present species in status surveys and inventories. We suspect strongly that this behavior is much more common across species than previous reports would suggest. We found four species that had not previously been reported in the peer-reviewed literature to chorus during the day: American Toad, Fowler's Toad (*Anaxyrus fowleri*), Blanchard's Cricket Frog, and the Pickerel Frog. This may constitute an important tool and consideration for both applied and theoretically-focused herpetologists. Because no animals were directly handled in this study, IACUC approval was not necessary.

Post-script: While this paper was in peer review and an unpublished version posted to BioRxiv (McCallum and McCallum 2018), a continental assessment of diurnal calling was performed in Australia (Callaghan and Rowley 2020) confirming further the widespread nature of diurnal calling.

Table 1. Observations of Anuran species at the Red River Research and Education Park, Shreveport, Louisiana and records of diurnal breeding choruses.

Species	Present?*	Calling Season (NAAMP)	Detection Window		Detectability	
			Earliest Diurnal chorusing	Latest Diurnal chorusing	No. of visits from first to last calling day N/T (%)	Total Visits N/T (%)
Blanchard's Cricket Frog ( <i>Acris blanchardi</i> )	Yes	March – Oct.**	15 March 2004	3 September 2004	72/87 (83%)	72/248 (29%)
Eastern Narrow-mouthed Toad ( <i>Gastrophryne carolinensis</i> )	Yes	May – July	4 June 2004	11 July 2004	9/19 (47%) (28 June – 1 July = 4/9 (44%) of calling days)	9/248 (3.6%)
Fowler's Toad ( <i>Anaxyrus fowleri</i> )	Yes	April – July	4 June 2004	1 July 2004	8/15 (53%) (27 June – 1 July = 5/8 (63%) of calling days)	8/248 (3.2%)
American Bullfrog ( <i>Lithobates catesbeianus</i> )	Yes	April – July	28 March 2004	27 June 2004	8/49(16%)	8/248 (3.2%)
Southern Leopard Frog ( <i>Lithobates sphenoccephalus</i> )	Yes	January – July	25 January 2004	1 March 2004	5/30 (17%)	5/248 (2%)
American Toad ( <i>Anaxyrus americanus</i> )	No	Est. Mar – June***	27 June 2004	19 July 2004	2/12 (17%)	2/248 (0.8%)
Bronze Frog ( <i>Lithobates clamitans</i> )	Yes	March – July	27 June 2004	11 July 2004	2/8 (25%)	2/248 (0.8%)
Pickrel Frog ( <i>Lithobates palustris</i> )	Maybe	March	1 February 2004	1 February 2004	--	1/248 (0.4%)
Cope's Gray Treefrog ( <i>Hyla chrysoscelis</i> )	Maybe	March – July	17 October 2004	17 October 2004	--	1/248 (0.4%)
Bird-voiced Treefrog ( <i>Hyla avivoca</i> )	Maybe	April – July	--	--	--	0/248 (0%)
Green Treefrog ( <i>Hyla cinerea</i> )	Yes	March – July	--	--	--	0/248 (0%)
Gray Treefrog ( <i>Hyla versicolor</i> )	Yes	April – June	--	--	--	0/248 (0%)
Squirrel Treefrog ( <i>Hyla squirrellea</i> )	Maybe	June	--	--	--	0/248 (0%)
Spring Peeper ( <i>Pseudacris crucifer</i> )	Maybe	January – May	--	--	--	0/248 (0%)
Cajun Chorus Frog ( <i>Pseudacris fouquettei</i> )	Yes	December – May	--	--	--	0/248 (0%)
Rio Grande Chirping Frog ( <i>Eleutherodactylus cystignathoides</i> )	Maybe	?	--	--	--	0/248 (0%)

\*Yes = physically observed in park, No = not physically observed at park or in area, Maybe = not physically observed in park but present nearby.

\*\* NAAMP surveys suggest March –July, but our personal observations in the area suggest this frog calls through October at night.

\*\*\*No NAAMP records in northern Louisiana, southern Arkansas or northeastern Texas. These dates based on the closest NAAMP route at Vicksburg National Battlefield, Mississippi (510610).

Table 2. Best Subsets Regression results for the possible interaction between the date, temperature, and wind speed on expression of diurnal calling in five species of anurans.

Blanchard's Cricket Frog ( <i>Acris blanchardi</i> )							
Vars	R <sup>2</sup>	R <sup>2</sup> <sub>adj</sub>	C-P	S	Date	Temp	Wind
1	24.1	23.7	21.8	0.4054		X	
1	18.8	18.4	39.1	0.4193	X		
2	29.4	28.7	6.5	0.3919	X	X	
2	26.0	25.3	17.5	0.4011		X	X
3	30.7	29.8	4.0	0.3889	X	X	X
American Bullfrog ( <i>Lithobates catesbeianus</i> )							
1	4.1	3.6	1.0	0.17987			X
1	0.9	0.5	8.5	0.18282		X	
2	4.5	3.6	2.0	0.17988		X	X
2	4.2	3.3	2.8	0.18018	X		X
3	4.5	3.2	4.0	0.18027	X	X	X
Eastern Narrow-mouthed Toad ( <i>Gastrophryne carolinensis</i> )							
1	4.8	4.3	4.8	0.18967		X	
1	2.7	2.3	9.8	0.19172	X		
2	6.0	5.2	3.6	0.18880	X	X	
2	5.2	4.4	5.6	0.18960		X	X
3	6.7	5.5	4.0	0.18854	X	X	X
Fowler's Toad ( <i>Anaxyrus fowleri</i> )							
1	3.6	3.2	5.0	0.18027		X	
1	2.4	2.0	8.0	0.18144	X		
2	5.0	4.1	3.8	0.17940		X	X
2	4.2	3.3	5.7	0.18016	X	X	
3	5.7	4.5	4.0	0.17910	X	X	X
Southern Leopard Frog ( <i>Lithobates sphenoccephalus</i> )							
1	0.6	0.2	0.6	0.14568			X
1	0.3	0.0	1.4	0.14592		X	
2	0.8	0.0	2.2	0.14586		X	X
2	0.8	0.0	2.2	0.14587	X		X
3	0.9	0.0	4.0	0.14613	X	X	X

Table 3. Results from Binomial logistic regression for the influence of the date, wind speed and temperature on the occurrence of calling by male Blanchard's Cricket Frogs (*Acris blanchardi*).

Response Information		
Variable	Value	Count
Calling	1	72
No calling	0	159
Missing values	--	17

  

Logistic Regression Table						95% CI	
Predictor	Coefficient	SE Coefficient	Z	P	Odds Ratio	Lower	Upper
Constant	-191.41	62.32	-3.20	0.001			
Date	0.00509	0.001641	3.10	0.002	1.01	1.00	1.01
Temperature	0.16651	0.03313	5.03	< 0.001	1.18	1.11	1.26
Wind Speed	0.3466	0.1440	2.41	0.016	1.41	1.07	1.88
Log-Likelihood	-101.431						

  

Test that all slopes are zero		
G	df	P
83.784	3	< 0.001

  

Goodness-of-Fit Tests			
Method	Chi Square	df	P
Pearson	181.425	227	0.988
Deviance	202.862	227	0.874
Hosmer-Lemeshow	26.494	8	0.001

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