Banisteria, Number 39, pages 34-46

Patterns of Frog and Toad Vocalization in Fairfax County, Virginia

Todd A. Tupper[1], Tatiana Galitzin, Christine Bozarth

Science, Technology, and Business Division
Northern Virginia Community College
Alexandria Campus
3001 North Beauregard Street
Alexandria, Virginia 22311

David M. Lawlor

Huntley Meadows Park
3701 Lockheed Boulevard
Alexandria, Virginia 22306

ABSTRACT

Anuran (frog and toad) call surveys are used to monitor long-term trends in anuran populations but survey efficacy is reduced if peak calling periods are unknown. We estimated peak calling activity for eight species (American Toad, Green Treefrog, Cope's Gray Treefrog, American Bullfrog, Green Frog, Pickerel Frog, Southern Leopard Frog, and Spring Peeper) in Fairfax County, Virginia. We identified significant interspecific differences in detection probabilities and days to first detection. Spring Peeper and American Bullfrog were the first and last anurans to initiate calling, respectively. Sampling at least five times during two sampling windows (ca. 27 March-17 April and ca. 15 May-16 July) is needed for long-term anuran monitoring. Minimum threshold temperatures required for vocalization increased as the season progressed, even during conditions that supported chorusing in weeks prior. Surveys should be rotated to avoid temporal biases and not be conducted when temperatures are below minimum thresholds.

Key words: anuran, monitoring, calling anuran surveys, vocalization, calling chronology.

INTRODUCTION

Anuran call surveys (CAS) are widely used to monitor long-term trends in anuran (frog and toad) populations, both at smaller, local scales (Steelman & Dorcas, 2010; Cook et al., 2011) and larger, statewide (Weir et al., 2005), regional (Weir et al., 2005), and national scales (Weir & Mossman, 2005). CAS are especially important because changes in anuran calling chronology could be a possible first indication of a biotic response to climate change (Gibbs & Breisch, 2001). CAS are also used for species-specific ecological studies (Tupper & Cook, 2008) and to assess the effectiveness of habitat restoration efforts (Stevens et al., 2002). Environmental factors such as rainfall, air temperature, water temperature (Pellet & Schmidt, 2005; Gooch et al., 2006), and time of year all interact to affect the timing and intensity of anuran calling activity (see Saenz et al., 2006) and consequently a researcher's chances of detecting anuran calls (Shirose et al., 1997).

These environmental factors vary across latitudes and even regionally within latitudes (e.g., from Rhode Island to Cape Cod, Massachusetts); as a result, so does anuran calling activity (Berven, 1982; de Solla et al., 2006; Tupper et al., 2007; Cook et al., 2011). Therefore, implementing a precise and efficient localized, long-term monitoring program can be challenging because it is most effective to design programs around peak calling activities, i.e., when chances of detecting vocalizations are highest (Crouch & Paton, 2002; Cook et al., 2011).

[1]Corresponding author: ttupper@nvcc.edu

Although studies have addressed anuran monitoring in southern New England (Crouch & Paton, 2002; Tupper et al., 2007; Cook et al., 2011) and the south Atlantic states (see Bridges & Dorcas, 2000; Dorcas et al., 2009; Steelman & Dorcas, 2010), to our knowledge systematically collected, non-anecdotal data are limited for the mid-Atlantic states (but see Weir et al., 2005; Brander et al., 2007). Though various works describe anuran breeding activities (Lee, 1973; Mitchell, 1979; Ernst et al., 1997) in northern Virginia and adjacent areas, to the best of our knowledge none have quantitatively approached this issue for the purpose of optimizing long-term monitoring programs. We present data collected from two seasons of CAS sampling at Huntley Meadows Park in Fairfax County, Virginia, that can be used to help guide implementation of long-term anuran monitoring programs in the mid-Atlantic states. Our goals were to (1) identify the most appropriate times of year and night (peak detection periods) and corresponding ambient temperatures to sample for anuran species with CAS; (2) to identify the number of sampling occasions needed during a species' peak detection period to achieve a 90% probability of at least one detection at an occupied site and (3) to calculate the number of wetlands needed to sample to estimate occupancy with a standard error (SE) of 0.10 (Cook et al., 2011).

MATERIALS AND METHODS

Study Area

Huntley Meadows Park (Fairfax County, Virginia; 38°45′20.95″N; 77°06′29.26″W) is a 577 ha park that is predominantly surrounded by densely populated suburban developments, except for a fragmented green corridor on the southeast side of the park (Fig. 1). The majority of the park (the central wetland) is within wet lowland formed by an early meander of the Potomac River. The central wetland is hydrologically connected to the majority of wetlands within the park. However, the vegetational communities existing in the different regions of the park range from early-successional wetlands to later-successional hardwood swamps. Consequently, the abiotic features of these wetlands are also quite different. Water can be tannin-lignin rich, cool, and acidic, to clearer, warm, and more neutral (DL, unpubl. data). All park wetlands are freshwater, and together with the biotic characteristics of the environment, form a biodiverse and important ecosystem in Fairfax County (http://www.fairfaxcounty.gov/parks/huntley/).

Site Selection

We used a stratified-random scheme to select 15 wetlands for CAS sampling. Using Google Earth version 6 (http://www.google.com/earth/index.html) at an 'eye altitude' of 4.19 km, we created a grid consisting of 122 220 m x 282 m cells over high-resolution satellite imagery of Huntley Meadows Park. We assigned each cell into one of our strata (northern, central, and southern regions of the park) and randomly selected five cells (> 200 m apart) in each region. We then sampled the wetland nearest the center of each selected cell using CAS methodology. We assigned each wetland to one of three calling survey routes (one route per aforementioned strata), each consisting of five wetlands (Fig 1). Selected study wetlands ranged from short-hydroperiod, fishless ephemeral wetlands, to permanently inundated wetlands containing fish.

Data Collection

We recorded up to four ordinal calling index values (0-3) following North American Amphibian Monitoring Program (NAAMP) guidelines (Weir & Mossman, 2005) to quantify anuran calling activity where 0 = no calls, 1 = calling but no overlap between calls, 2 = intermediate overlap and 3 = continuously overlapping calls. Sites were typically sampled between 30-min after sunset and 2400 h (Weir & Mossman, 2005). The order in which sites were sampled was rotated to avoid temporal sampling biases. Because it is well known that detection probability is greatly affected by air and surface water temperatures (Gooch et al., 2006;

Fig. 1. Huntley Meadows Park, Fairfax County, Virginia (38°45′20.95″N; 77°06′29.26″W). Black and white circles in enlarged area represent calling survey points.

Steelman & Dorcas, 2010; Cook et al., 2011) and that both air and water temperatures are good predictors of anuran body temperatures (Fouquette, 1980), we recorded ambient temperatures during each sampling event. We placed a thermometer approximately 1.5 m above the ground for 5 min to measure air temperature (°) and we placed a thermometer between 1.5 and 3 cm beneath the water's surface for 5 min to measure surface water temperature (°C). In accordance with NAAMP guidelines (Weir & Mossman, 2005), we also recorded sky conditions, noise disturbance, and wind codes (on the Beaufort scale).

Nightly and Seasonal Calling Chronology

We were interested in determining when, within established NAAMP CAS sampling guidelines (ca. 30 min after sunset to ca. 2400 h), detected species were encountered while chorusing so that future sampling could accommodate known peak periods of nightly activity. We accomplished this by calculating mean, 95% confidence interval (CI), and range of time (minutes) after sunset that chorusing and non-chorusing events occurred for each species. We examined differences in timing of calling between chorusing (calling index ≥ 1) and non-chorusing (calling index = 0) events with 2-sample t-tests (Zar, 1999). To identify peaks in calling activity and describe seasonal calling chronology, we grouped surveys by sampling week (a 7-day interval starting from the first survey) and calculated a naïve detection probability (p; number of times a species was detected/number of samples per week) per species, per sampling week. We defined peaks as any sampling week that yielded a $p \geq 0.90$*maximum p). We used a one-way analysis of variance (ANOVA) and Tukey's post-hoc multiple comparison (Zar, 1999) to identify interspecific differences in detection probabilities (data square-root arc sin transformed). Residual plots were used to assess equality of variances and normality. Interspecific differences in calling chronology (days to first detection) were assessed with a Pearsons chi-square statistic (Zar, 1999).

Ambient Temperature

In multivariate analyses, Cook et al. (2011) found that surface water temperature had a larger effect on anuran calling activity than air temperature. Thus, we chose to focus our ambient temperature analyses on surface water temperature. We examined differences in mean surface water temperatures (grouped by sampling week) between chorusing and non-chorusing events with paired samples t-tests or one-sample Wilcoxon signed-rank tests. Paired-samples t-tests were used to examine differences in annual rainfall and temperature. Normality was assessed with normal probability plots and Kolmogorov-Smirnov tests and equality of variances was assessed with Levene's test for equality of variance (Zar, 1999).

Determining a Sampling Regime

MacKenzie & Royle (2005) define an "optimal" sampling scheme as one that provides an 85% to 95% probability of confirming that a target species occupies a site. Thus, for each species, we estimated the number of sampling occasions per site needed to achieve 90% probability of detecting the target species (see Cook et al., 2011) at least once during its peak calling period in a given year at occupied sites using the formula $p^* = 1 - (1 - p)^k$, where p = maximum naïve detection probability and k = number of sampling occasions/site (adapted from MacKenzie & Royle, 2005). We calculated the number of wetlands necessary to sample to estimate future occupancy (Ψ) rates ($\alpha = 0.10$) with equation 6.3 in MacKenzie et al. (2006).

Microsoft Excel 2007 was used to create figures, calculate equations presented in Mackenzie et al. (2006), and compute some descriptive statistics (standard deviation [SD], 95% CI). Additional descriptive statistics and hypothesis tests were completed in Minitab version 14 (www.minitab.com). Maps were created with Google Earth version 6 and Microsoft PowerPoint 2007. Because anuran breeding behavior can be highly variable between years (Bishop et al., 1997), we pooled data from 2009 and 2010 to more accurately describe patterns in anuran calling chronology.

RESULTS

Descriptive Statistics, Calling Chronology, and Sampling Windows

We conducted a total of 775 calling surveys (CAS); 390 in 2009 and 385 in 2010. A mean of 12.2 (SD = 6.1) and 10.7 (SD = 4.6) CAS per sampling week were conducted in 2009 and 2010, respectively. The annual mean temperatures for 2009 and 2010 were 14.3°C (SD = 9.41) and 15.6°C (SD = 10.4), respectively. Annual mean rainfall was 0.37 cm in 2009 (SD = 0.76) and 0.27 cm in 2010 (SD = 0.88). We found no significant differences in monthly mean rainfall and temperature between years (rainfall $t = -2.05$, $P > 0.05$; temperature $t = 1.23$, $P > 0.05$).

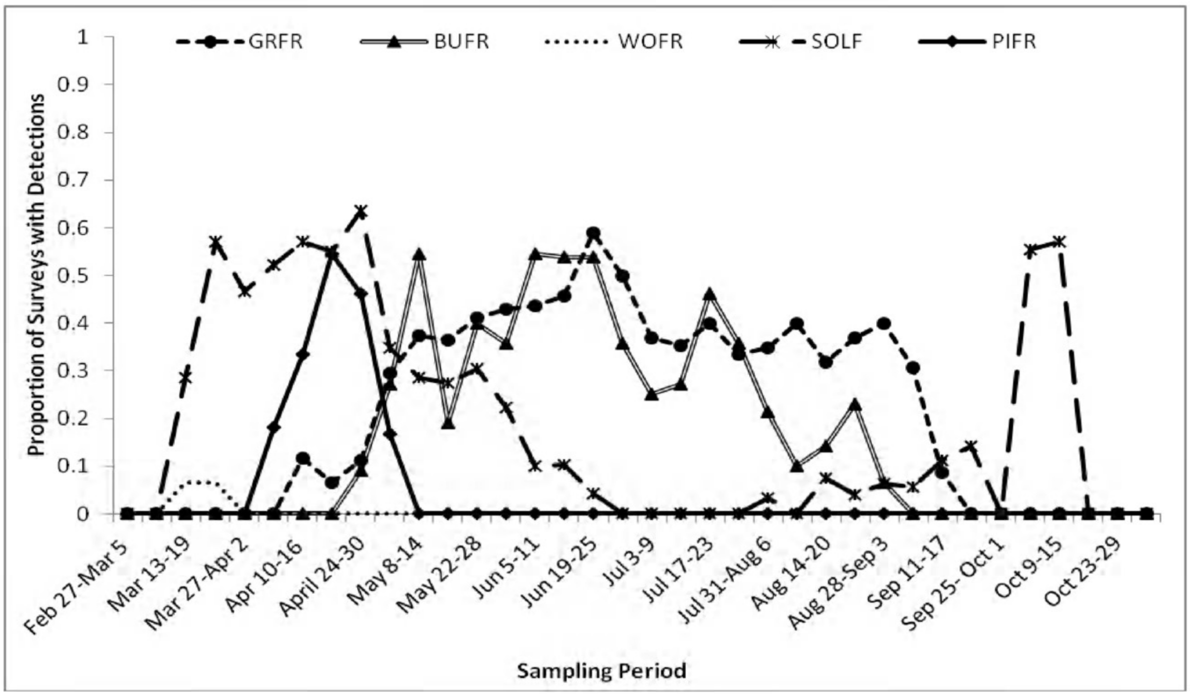
Ten species were identified (Table 1), but Fowler's Toad (*Anaxyrus fowleri*) and Wood Frog (*Lithobates*

Table 1. Occupancy data (detections[1]; non-detections[-]) for anurans identified with CAS at Huntley Meadows Park. % Total Species = % of total species present at a given site; % Sites Occupied = naïve occupancy calculations (# of sites with detections/total # of sites sampled), AMTO = American Toad (*Anaxyrus americanus*), FOTO = Fowler's Toad (*Bufo fowleri*), CGTF = Cope's Gray Treefrog (*Hyla chrysoscelis*), GRTF = Green Treefrog (*Hyla cinerea*), BUFR = American Bullfrog (*Lithobates catesbeianus*), GRFR = Green Frog (*Lithobates clamitans*), PIFR = Pickerel Frog (*Lithobates palustris*), SLFR Southern Leopard Frog (*Lithobates sphenocephalus*), WOFR = Wood Frog (*Lithobates sylvaticus*), and SPPE = Spring Peeper (*Pseudacris crucifer*).

Sites	AMTO	FOTO	CGTF	GRTF	BUFR	GRFR	PIFR	SLFR	WOFR	SPPE	% Total Species
AUG	1	1	1	-	-	1	1	1	1	1	80
ARMY	-	-	-	-	-	-	-	-	-	1	10
BCWL	1	-	1	1	1	1	1	1	-	1	80
CG	1	-	1	-	-	1	-	1	-	1	50
DCGL	-	-	-	-	-	-	-	1	-	1	20
DITCH	-	-	-	-	-	1	-	1	-	1	30
DRP	-	-	1	1	1	1	1	1	-	1	70
MDW	1	-	1	-	-	1	-	1	-	1	50
MSL	-	-	-	-	-	-	-	1	-	1	20
NCWL	1	-	1	1	1	1	1	1	-	1	80
NSL	-	-	1	-	-	-	-	1	-	-	20
PT	1	-	1	-	1	1	1	1	-	1	70
PWL	1	1	1	-	-	1	1	1	-	1	70
SCWL	1	1	1	1	1	1	1	1	-	1	90
SSL	1	-	1	-	-	1	-	1	-	1	50
% Sites Occupied	60	20	73	27	33	73	47	93	7	93	-

sylvaticus) were detected on <4 sampling occasions so data are not meaningful. Full choruses (i.e., calling index values = 3) were detected in all species except Pickerel Frogs (*L. palustris*). Chorusing events for Green Treefrog (*Hyla cinerea*) tended to occur slightly nearer sunset (mean = 120.9 [95% CI = 17.2] min after sunset) than non-chorusing events (mean = 149.4 [95% CI = 23.5] min after sunset; t = 1.96, df = 101; P = 0.05). Diel differences were not detected in other species. Seasonal calling chronologies were described for all species, and the number of days to first detection differed significantly between species (X^2= 62.5; df = 9; $P < 0.05$; Fig. 2), with Spring Peeper and American Bullfrog (*L. catesbeianus*, hereafter Bullfrog) being the first and last species, respectively, to commence calling (Fig. 2). We found interspecific differences in detection probabilities ($F = 3.57_{7,\ 111}$; $P < 0.05$) with two homogenous subgroups identified. Subgroup A (Pickerel Frog and American Toad [*A. americanus*]) had lower naïve detection probabilities than subgroup B (Green Frog [*L. clamitans*], Bullfrog, Green Treefrog, Spring Peeper [*Pseudacris crucifer*], Southern Leopard Frog [*L. sphenocephalus*], and Cope's Gray Treefrog [*H. chrysoscelis*]). Peak activity periods also varied depending on the species. We identified two sampling windows (ca. 27 March-17 April [window 1] and ca. 15 May-16 July [window 2]) appropriate for long-term monitoring. Peaks for American Toad, Pickerel Frog, Southern Leopard Frog, and Spring Peeper occurred within sampling window 1 and peaks for Cope's Gray Treefrog, Green Treefrog, Bullfrog, and Green Frog occurred within sampling window 2 (Table 2).

(a) True Frogs



(b) Toads, Chorus Frogs, and Treefrogs

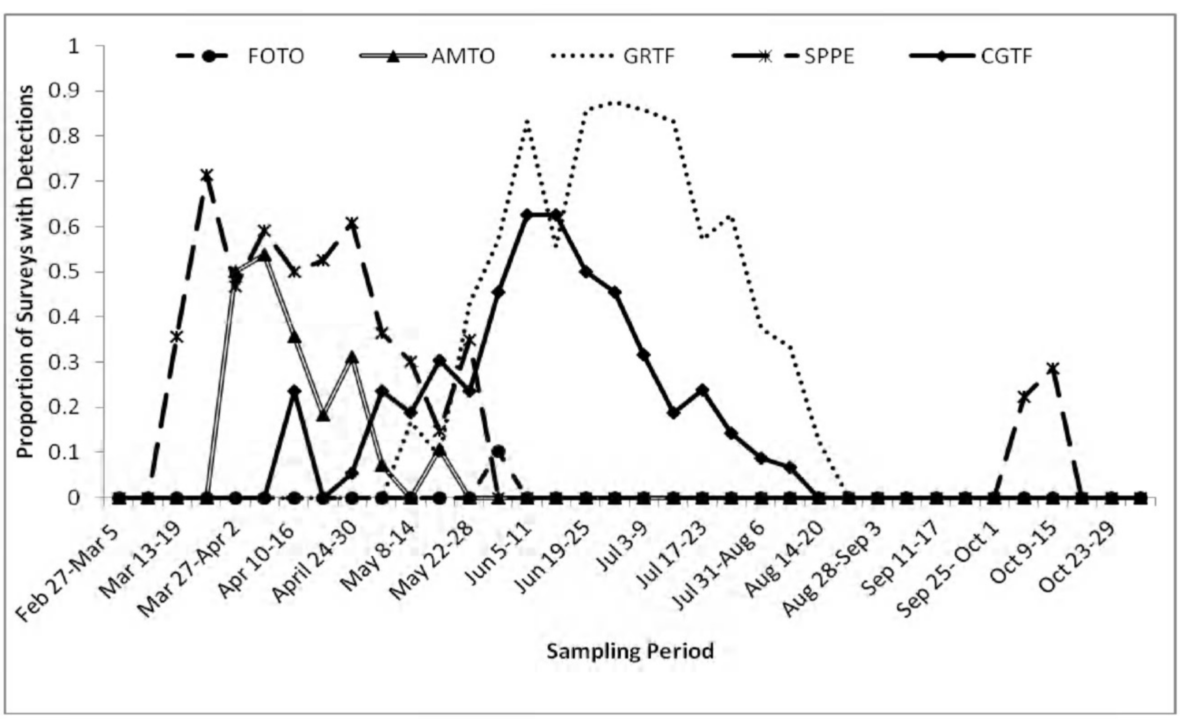


Fig. 2. Calling chronology for true frogs (a) and toads, chorus frogs, and treefrogs (b) detected at Huntley Meadows Park. Data are pooled from 2009 and 2010.

Table 2. Dates of calling activity and peak calling periods for anurans detected with CAS. We were unable to determine peak calling periods for Fowler's Toad and Wood Frog because of too little data.

Species	Dates of Calling Activity	Peak Calling Periods
American Toad	3/23-5/8	4/10-4/30
Fowler's Toad	5/23-5/27	---
Cope's Gray Treefrog	4/5-7/31	5/29-6/11
Green Treefrog	5/6-8/10	5/20-5/26; 6/12-6/25
American Bullfrog	4/22-8/23	5/1-5/7; 5/29-6/18; 7/10-7/16
Green Frog	4/5-9/5	6/12-6/25
Pickerel Frog	4/1-4/27	4/10-4/23
Southern Leopard Frog	3/9-6/12; 8/8-10/8	4/10-4/23; 9/25-10/8
Wood Frog	3/11-3/19	---
Spring Peeper	3/7-5/21	3/13-3/19; 3/27-4/2; 4/10-4/23

Ambient Temperature and Sampling Regime

Chorusing events for all species except pickerel, southern leopard, and gray treefrogs tended to occur when surface water temperatures were significantly warmer than did non-chorusing events (within the range of breeding activity). The minimum threshold temperatures required for vocalization increased as the season progressed (Table 3). For example, during the first week of May we detected Bullfrog when surface water temperatures averaged 16.9°C (SD = 4.07). In mid-July, surface water temperatures were considerably warmer on nights when this species was not heard chorusing (mean = 21.3°C; SD = 0.35; Fig. 3). Choruses during this time period (i.e., July 17-23) occurred at an average temperature of 23.8°C (SD = 2.32). Similar patterns were seen in all other species.

The optimal number of sampling occasions needed to detect each species (per site with a 90% probability of detection) during peak calling periods ranged from 2 to 24 (mean = 7.9; SD = 10.8), with $\leq$5 sampling occasions necessary for 8 of the 10 species. The number of wetlands needed to survey to estimate Ψ (with SE = 0.10) ranged from 7–42 (mean = 24.5; SD = 10.5; Table 4).

DISCUSSION

Applications and Future Monitoring

Many studies describe various aspects of vocalization in species detected in this study (e.g., Wright, 1914; Wright & Wright, 1949; Wiewandt, 1969; Garton & Brandon, 1975; Gerhardt & Klump, 1988; Given, 2002) and aspects of anuran breeding phenology have been documented since the early 1900s (e.g., Wright, 1914; Harper, 1928; Babcock & Hoops, 1940). This study yields specific information important for long-term anuran monitoring in the northern mid-Atlantic States. Two sampling windows are needed to successfully monitor the eight species (ca. 27 March-17 April [window 1] and ca. 15 May-16 July [window 2]) and we estimate that a total of five sampling occasions during these windows are necessary to successfully detect vocalizations. Because chorusing events for Green Treefrog tended to occur nearer to sunset, it is essential that the order in which sites are sampled be rotated. Sites that are consistently sampled later than others may result in artificially low detection probabilities and inaccurate occupancy rates.

We provide a range of minimum temperatures during which vocalizations were documented and found that the threshold temperatures for vocalization tend to increase as the season (within a species' range of calling activity) progressively increases even if lower temperatures, which supported calling in weeks prior, occur. Temperature must be considered in conjunction with time of year (Table 3).

True Frogs (Family Ranidae)

As reported by Babcock & Hoops (1940), Emlen (1976), Klemens (1993), Mohr & Dorcas (1999), Crouch & Paton (2002), Weir et al. (2005), and Cook et al. (2011), our data show that Bullfrog has a somewhat protracted calling season. Detection probabilities are highest from mid-May to the end of June, with a central "peak" occurring between 29 May and 11 June. Our data differ from studies conducted in southern New England where peaks are considerably later, occurring

Table 3. Minimum surface water temperatures recorded during detection events throughout each species' calling season. * = that surface water temperature had a significant effect on calling. Significance was determined with a paired samples t-test or Wilcoxon signed rank test (α= 0.05). Contact corresponding author for *P*-values and test statistics.

Week Interval	AMTO*	FOTO	CGTF*	GRTF	BUFR*	GRFR*	PIFR	WOFR	SLFR	SPPE*
Feb 27-Mar 5	-	-	-	-	-	-	-	-	-	-
Mar 6-12	-	-	-	-	-	-	-	-	-	-
Mar 13-19	-	-	-	-	-	-	-	14.0	10.0	10.0
Mar 20-26	-	-	-	-	-	-	-	12.0	9.5	9.0
Mar 27-Apr 2	9.2	-	-	-	-	-	-	-	6.7	5.6
Apr 3-9	11.8	-	-	-	-	-	15.5	-	11.7	11.7
Apr 10-16	13.9	-	17.8	-	-	19.5	6.1	-	6.1	10.6
Apr 17-23	12.8	-	-	-	-	16.0	12.2	-	10.0	10.0
April 24-30	13.9	-	19.0	-	17.0	15.3	15.0	-	11.7	11.7
May 1-7	16.7	-	13.0	-	13.0	13.0	15.0	-	13.0	13.0
May 8-14	-	-	17.8	20.5	13.9	13.9	-	-	13.9	15.3
May 15-21	16.1	-	15.0	18.3	16.0	14.8	-	-	13.5	15.0
May 22-28	-	-	18.5	15.0	15.0	15.0	-	-	12.2	14.4
May 29-Jun 4	-	18.8	17.2	20.5	20.3	13.3	-	-	13.3	-
Jun 5-11	-	-	18.9	20.0	18.9	18.9	-	-	20.0	-
Jun 12-18	-	-	18.0	20.0	20.0	18.0	-	-	18.0	-
Jun 19-25	-	-	21.0	22.5	22.5	21.5	-	-	23.5	-
Jun 26-Jul 2	-	-	22.5	22.0	22.0	22.0	-	-	-	-
Jul 3-9	-	-	23.5	23.5	23.5	23.5	-	-	-	-
Jul 10-16	-	-	21.0	21.0	21.0	21.0	-	-	-	-
Jul 17-23	-	-	21.5	21.5	20.5	20.5	-	-	-	-
Jul 24-30	-	-	23.5	25.8	23.0	23.0	-	-	-	-
Jul 31-Aug 6	-	-	24.0	24.0	24.0	24.0	-	-	24.0	-
Aug 7-13	-	-	25.0	23.8	25.0	23.8	-	-	-	-
Aug 14-20	-	-	-	26.3	24.0	23.0	-	-	24.0	-
Aug 21-27	-	-	-	-	23.3	23.0	-	-	23.3	-
Aug 28-Sep 3	-	-	-	-	25.0	22.8	-	-	24.5	-
Sep 4-10	-	-	-	-	-	18.5	-	-	18.5	-
Sep 11-17	-	-	-	-	-	19.0	-	-	20.0	-
Sep 18-24	-	-	-	-	-	-	-	-	18.5	-
Sep 25- Oct 1	-	-	-	-	-	-	-	-	-	-
Oct 2-8	-	-	-	-	-	-	-	-	15.8	18.3
Oct 9-15	-	-	-	-	-	-	-	-	11.0	12.8
Oct 16-22	-	-	-	-	-	-	-	-	-	-
Oct 23-29	-	-	-	-	-	-	-	-	-	-
Oct 30-Nov 6	-	-	-	-	-	-	-	-	-	-

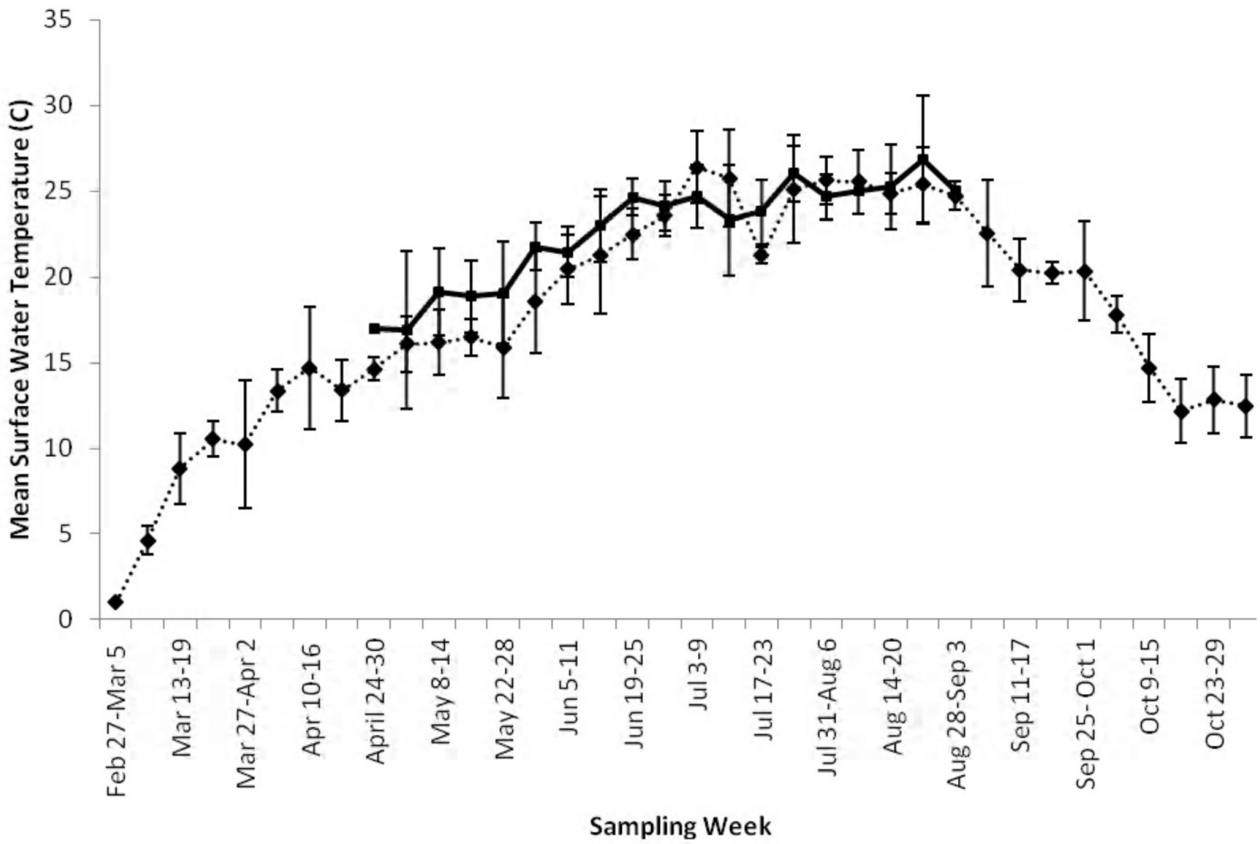


Fig. 3. Mean surface water temperatures recorded throughout the American Bullfrog calling season (solid line = detections, dotted line = non-detection, whiskers = 95% CI). Surveys that resulted in detections yielded warmer surface temperatures than surveys resulting in non-detections. The non-detections recorded during cooler temperatures later in the season occurred at warmer temperatures than calling events recorded earlier in the season. This pattern indicates changing threshold temperatures for calling throughout the season. This trend was similar for all species detected. Contact corresponding author for additional figures.

Table 4. Power analysis and sites needed to estimate Ψ. Ψ = occupancy rates, Max Naïve p = maximum naïve detection probabilities. The next two columns from left to right are: [1]the number of samples needed to detect a given species at sites where present (with 90% probability of detection) and [2]the number of sites needed to estimate site occupancy rates with SE = 0.10. * = too few detections, data should be interpreted cautiously.

Species	Ψ	Max Naïve p	Sampling Occasions[1]	Wetlands[2]
American Toad	0.600	0.538	3	35
Fowler's Toad*	0.200	0.103	21	19
Cope's Gray Treefrog	0.733	0.313	5	42
Green Treefrog	0.267	0.857	2	20
American Bullfrog	0.333	0.545	3	28
Green Frog	0.733	0.588	3	28
Pickerel Frog	0.467	0.545	3	33
Southern Leopard Frog	0.933	0.636	3	13
Wood Frog*	0.067	0.067	34	7
Spring Peeper	0.933	0.714	2	21

throughout July in Rhode Island (Crouch & Paton, 2002) and Massachusetts (Cook et al., 2011). Our recorded intra-seasonal range of vocalization for this species is similar to anecdotal accounts of vocalization in New York (Wright & Wright, 1949; Bury & Whelan, 1984) and Connecticut (Klemens, 1993). Our Bullfrog data more closely resemble patterns described by Weir et al. (2005), where an estimated seasonal peak occurred at ca. 31 May throughout eastern and central Maryland. Ernst et al. (1997) report calling beginning in late April or early May in northern Virginia. Though our earliest identified vocalization of Bullfrog was 22 April in this study, we have observed vocalizations (not full choruses) in March at the Smithsonian Environmental Research Center, Edgewater, Maryland and in Arlington County, Virginia. All accounts of Bullfrog calling from the southeastern United States (the Carolinas and Georgia) in the 1920s and 1930s by Harper (1934) occurred within, or two weeks prior to, our observed range of activity.

Mohr & Dorcas (1999) and Bridges & Dorcas (2000) indicate that peak calling activity for Bullfrog occurs between ca. 0400 h and 0600 h, well after established NAAMP protocol guidelines. However, like Cook et al. (2011), we found that NAAMP guidelines seem appropriate for detection of Bullfrog, as we detected this species on 75/105 sampling events within the range of its calling activity.

The Green Frog breeding season also appeared protracted (which appears typical of this species, see Wells, 1977; Klemens, 1993; Ernst et al., 1997; Mohr & Dorcas, 1999; Crouch & Paton, 2002; Cook et al., 2011). Peak periods of activity for Green Frog on Lower Cape Cod, Massachusetts (ca. 30 June – 26 July) and in Washington County, Rhode Island (Crouch & Paton, 2002; ca. 20-24 July) were expectedly later than in our study (between 12 and 25 June) and in Maryland ([ca. 31 May; Weir et al., 2005]; Ernst et al., 1997). In Connecticut, Klemens (1993) reported calling throughout our documented range of calling for this species. In areas adjacent to Klemens' (1993) study sites, Babbitt (1937) and Wright & Wright (1949) indicated that the onset of chorusing occurs from mid to late May, which is approximately one month later than documented in northern Virginia and approximately two months later than documented in Texas (Saenz et al., 2006). Interestingly, the earliest record of Green Frog vocalization by Harper (1934) from the early 1930s in Okefinokee Swamp, Georgia occurred six days later (11 April 1933) than in our study.

Using an automated recording system, Cook et al. (2011) determined that peak diel activity for Green Frog occurred in Massachusetts at ca. 2400 h, whereas Mohr & Dorcas (1999), also employing an automated recording system, reported that it occurred at ca. 0400 h in South Carolina. The actual peak diel calling activity for Green Frog in the mid-Atlantic likely occurs before 0400 h and after 2400 h, well outside the NAAMP guidelines. This suggestion is based on variation in peak calling times associated with latitudinal differences in Cook et al. (2011) and Mohr & Dorcas (1999). Nevertheless, in our study, Green Frog appears to have called frequently enough during NAAMP guidelines to ensure detections (we detected Green Frog on 155/295 of sampling events during the range of its calling activity).

Southern Leopard Frog is known as a spring and fall breeder (Caldwell, 1986; Gibbons & Semlitsch, 1991; Roble, 2003; Gibson & Sattler, 2010). However, Bridges & Dorcas (2000) documented consistent calling activity throughout July 1997 in South Carolina. We documented consistent calling activity between 9 March and 12 June, and then again between 8 August and 8 October. No calling was detected in July 2009 or 2010. Weir et al. (2005) also defined a seasonal calling chronology for this species, but their estimated chronology contains only a single peak on ca. 31 May, which is one month later than our first peak (10-23 April) and does not account for a fall peak. This variation is surprising considering the close proximity of our respective study sites (both 41° N latitude), indicating the importance of increasing interannual sampling to ensure accurate description of anuran calling chronology.

In Maryland, Lee (1973) found that Southern Leopard Frog calls began in February and ended in June. His findings and anecdotal observations by Ernst et al. (1997) appear consistent with our early peak of Southern Leopard Frog vocalization, but also do not account for late summer/early fall vocalizations. The onset of Southern Leopard Frog calling in North Carolina occurred later than in our study (20 and 21 February, Todd et al. [2003]; Steelman & Dorcas [2010]). Though it was known then that calling occurred in months prior, the earliest date of Southern Leopard Frog calls recorded in North Carolina in the early 1930s occurred on 2 April, which seems late for the region (Harper, 1935).

Harper (1935) indicated that the strongest choruses of Southern Leopard Frog occur between midnight and dawn. He attributed this diel pattern to a preference for calling when nightly temperatures drop. He suggested that, "the affinities of this species may be boreal rather than austral for its closest relative, *Rana pipiens*, is one of the most northerly ranging of American frogs." This hypothesis provides an important perspective given climate change and its suggested effect on anuran calling chronology (Gibbs & Breisch, 2001): how would climactic warming affect this boreal species? See Bridges & Dorcas (2000), Todd et al. (2003), and Steelman & Dorcas (2010) for more data on diel chronology in this species.

Activity for Pickerel Frog was abbreviated in comparison to other ranids detected in our study. Our results are comparable to those of Weir et al. (2005) and concur with observations made by Ernst et al. (1997). Though we did not confirm Pickerel Frog vocalizations in March (as did Ernst et al. [1997]), we have anecdotally heard calls in March in northern Virginia and Maryland. In southern New England, peaks occurred later in the season, within the first three weeks of May (Crouch & Paton, 2002; Cook et al., 2011). Onset of calling occurs in late February in North Carolina (Todd et al., 2003) and as early as January in Texas (Sanez et al., 2006). Todd et al. (2003) reported a diel peak within NAAMP guidelines (at ca. 2100 h), with vocalizations continuing into the early morning hours.

American Toad (Family Bufonidae)

American Toad also had a short (and discontinuous) calling season which can complicate monitoring. Our results are similar to Weir et al. (2005) and consistent with observations by Ernst et al. (1997), but as expected, are somewhat earlier than in Rhode Island (peak between 15-21 May; Crouch & Paton, 2002), Connecticut and New York (late April and May; Wright & Wright, 1949; Klemens, 1993). American Toad was heard vocalizing on 2 June 1934 in Georgia (elevations of 947 and 1353 m) and on 19 June 1934 (elevation 426 m) in Tennessee (ambient temp was ca. 14°C; Harper, 1935), which is surprisingly late considering the southern latitude.

Chorus Frogs and Treefrogs (Family Hylidae)

Spring Peeper yielded high detection probabilities (similar to Crouch & Paton [2002], Weir et al. [2005], and Cook et al. [2011]) and displayed a relatively continuous calling season. This continuity is advantageous as its peak calling period is relatively wide, providing a large sampling window. Onset of Spring Peeper calling began considerably earlier in this study (7 March, which is later than reported by Ernst et al., [1997]) than in New England (Crouch & Paton, 2002; Cook et al., 2011), but was much later than in the Carolinas (Martof et al., 1980; Steelman & Dorcas, 2010) and Texas (Saenz et al., 2006), where calling was recorded as early as January.

Spring Peeper calling chronology in New York (Wright & Wright, 1949), Connecticut (Klemens, 1993), Massachusetts (Cook et al., 2011), and Rhode Island (Crouch & Paton 2002) appears more similar to patterns seen in Maryland and Virginia (Mitchell, 1979) than those of the coastal southeastern United States where chorusing can be heard from October to March (Martof et al., 1980). Surprisingly, all accounts of late winter/spring calling from Florida, Georgia, Kentucky, and Tennessee in 1934 (Harper, 1935) occurred within or later than winter/spring Spring Peeper activity in this study.

Green Treefrog had approximately one month of frequent and continuous calling activity with a peak in late May and in mid to late June. Our intraseasonal data are consistent with Martof et al. (1980) and Ernst et al. (1997). Our diel data concur with Mohr & Dorcas (1999) and with Garton & Brandon (1975), who indicate that chorusing declines sharply between 2250 h and 2400 h.

Our estimated peak calling range for Cope's Gray Treefrog (29 May-11 June) is consistent with other findings in the region (Ernst et al., 1997; Weir et al., 2005). Our data also agree with Martof et al. (1980), who indicate that calling activity in Virginia and the Carolinas for "gray tree frogs" (combining observations on the sibling species *H. chrysoscelis* and *H. versicolor*) occurs from May to August. Harper (1935) described gray treefrog calling in the southeastern United States but also did not distinguish between these two species. Interestingly, all but one of his observations from the southeast (2 April 1933, North Carolina) occurred within our range of activity (4/5-7/31).

CONCLUSIONS

Though our results are similar to observations and studies from Maryland and Virginia, we identified data necessary for localized long-term anuran monitoring programs. Monitoring anuran breeding activity is important because shifting calling chronologies is a possible indication of biotic response to climate change (Gibbs & Breisch, 2001). Calls of most species identified in this study were also observed some 80 years ago in the Southeast by Harper (1935). It appears that onset of calling for species in both studies are nearly identical, which is surprising. We expected that initiation of calling in the Southeast would be considerably earlier than in the mid-Atlantic (given the typically warmer southern climates). We do not know if Harper's (1935) study began later in the season, if the onset of calling in the Southeast is typical in regions where data were collected, or if results of our and other recent studies indicate climactic warming (see Gibbs & Breisch, 2001).

With the exception of Harper's (1935) observations, species detected at Huntley Meadows Park that were also detected in study areas farther north initiate calling earlier than in the north, but later than in the south. The sequential order in which species vocalized was remarkably similar to other regions of the United States and Canada (Klemens, 1993; Bishop et al., 1997; Lepage et al., 1997; Brodman & Kilmurray, 1998; Mossman et al., 1998; Varhegyi et al., 1998; Crouch & Paton, 2002; Saenz et al., 2006; Cook et al., 2011) and supports what naturalists have observed, albeit less quantitatively, for decades.

ACKNOWLEDGEMENTS

We especially thank Emily Osborne, James Sinks, Adam Bucher, Pilar Suber, and Debbie Shaffer for helping TG conduct the calling surveys. The visitor center staff and many volunteers helped TG with fieldwork. Dr. Steve Roble provided helpful comments and Kevin Munroe approved this project.

LITERATURE CITED

Babbit, L. H. 1937. The Amphibia of Connecticut. Bulletin of the State Geological and Natural History Survey of Connecticut 57: 1-50.

Babcock, H. L, & I. Hoopes. 1940. An almanac of frogs and toads. New England Naturalist 6: 7-9.

Berven, K. A. 1982. The genetic basis of altitudinal variation in the Wood Frog *Rana sylvatica*. I. An experimental analysis of life history traits. Evolution 36: 962-983.

Brander, S. M., J. A. Royle, & M. Eames. 2007. Evaluation of the status of anurans on a refuge in suburban Maryland. Journal of Herpetology 41: 52-60.

Bridges, A. S., & M. E. Dorcas. 2000. Temporal variation in anuran calling behavior: implications for surveys and monitoring programs. Copeia 2000: 587-592.

Brodman, R., & M. Kilmurray. 1998. Status of amphibians in northwestern Indiana. Pp 125-136 *In* M. J. Lannoo (ed.), Status and Conservation of Midwestern Amphibians. University of Iowa Press, Iowa City, IA.

Bury, R. B., & J. A. Whelan. 1984. Ecology and management of the bullfrog. USDI: Fish and Wildlife Service, Resource Publication 155: 1-23.

Caldwell, J. P. 1986. Selection of egg deposition sites: A seasonal shift in the Southern Leopard Frog, *Rana sphenocephala*. Copeia 2003: 249-253.

Cook, R. P., T. A. Tupper, P. W. C. Paton, & B. C. Timm. 2011. Effects of temperature and temporal factors on anuran detection probabilities at Cape Cod National Seashore, Massachusetts, USA: Implications for long-term monitoring. Herpetological Conservation and Biology 6: 25-39.

Crouch, W. B., & P. W. C. Paton. 2002. Assessing the use of call surveys to monitor breeding anurans in Rhode Island. Journal of Herpetology 36: 185-192.

de Solla, S. R., K. J. Fernie, G. C. Barrett, & C. A. Bishop. 2006. Population trends and calling phenology of anuran populations surveyed in Ontario estimated using acoustic surveys. Biodiversity and Conservation 15: 3481-3497.

Dorcas, M. E., S. J. Price, S. C. Walls, & W. J. Barichivich. 2009. Auditory monitoring of anuran populations. Pp. 281-298 *In* C. K. Dodd (ed.), Amphibian Ecology and Conservation: A Handbook of Techniques. Oxford University Press, Oxford, UK.

Emlen, S. T. 1976. Organization and mating strategies in the bullfrog. Behavioral Ecology and Sociobiology 1: 283-313.

Ernst, C. H., S. C. Belfit, S. W. Sekscienski, & A. F. Laemmerzahl. 1997. The amphibians and reptiles of Ft. Belvoir and northern Virginia. Bulletin of the Maryland Herpetological Society 33: 1-62.

Fouquette, M. J. 1980. Effect of environmental temperatures on body temperature of aquatic-calling anurans. Journal of Herpetology 14: 347-352.

Garton, S. G., & R. A. Brandon. 1975. Reproductive ecology of the Green Tree Frog *Hyla cinerea* in southern Illinois. Herpetologica 31: 150-161.

Gerhardt, C. H., & G. M. Klump. 1988. Masking of acoustic signals by the chorus background noise in the Green Tree Frog: A limitation on mate choice. Animal Behavior 36: 1247-1249.

Gibbons, J. W., & R. D. Semlitsch. 1991. Guide to the Reptiles and Amphibians of the Savannah River Site. University of Georgia Press, Athens, GA. 131 pp.

Gibson, J. D., & P. Sattler. 2010. *Lithobates sphenocephalus* (Southern Leopard Frog). Catesbeiana 30: 30-31.

Given, M. F. 2002. Interrelationships among calling effort, growth rate and chorus tenure in *Bufo fowleri*. Copeia 2002: 979-987.

Gooch, M. M., A. M. Heupel, S. J. Price, & M. E. Dorcas. 2006. The effects of survey protocol on detection probabilities and site occupancy estimates of summer breeding anurans. Applied Herpetology 3: 129-142.

Harper, F. 1935. Amphibians of the southeastern states. American Midland Naturalist 16: 275-310.

Klemens, M. W. 1993. Amphibians and Reptiles of Connecticut and Adjacent Regions. Connecticut State Geological and Natural History Survey, Hartford, CT. 318 pp.

Lazell, J. D. 1976. This Broken Archipelago: Cape Cod, the Islands, Amphibians and Reptiles. Demeter Press, New York, NY. 260 pp.

Lepage, M. L., R. Courtois, C. Daigle, & S. Matte. 1997. Surveying calling anurans in Quebec using volunteers. Pp. 128-140 *In* D. M. Green (ed.), Amphibians in Decline: Canadian Studies of Global Problems. Society for the Study of Amphibians and Reptiles, Saint Louis, MO.

MacKenzie, D. I., J. D. Nichols, J. A. Royle, K. H. Pollock, L. L. Bailey, & J. E. Hines. 2006. Occupancy Estimation and Modeling: Inferring Patterns and Dynamics of Species Occurrence. Elsevier, New York, NY. 324pp.

MacKenzie, D. I., & J. A. Royle. 2005. Designing occupancy studies: general advice allocating survey effort. Journal of Applied Ecology 42: 1105-1114.

Mohr, J. R., & M. E. Dorcas. 1999. A comparison of anuran calling patterns at two Carolina bays in South Carolina. Journal of the Elisha Mitchell Scientific Society 115: 63-70.

Mossman, M. J., L. M. Hartman, R. Hay, J. R. Sauer, & B. J. Dhuey. 1998. Monitoring long-term trends in Wisconsin frog and toad populations. Pp. 169-205 *In* M. J. Lanoo (ed.), Status and Conservation of Midwestern Amphibians. University of Iowa Press, Iowa City, IA.

Pellet, J., & B. R. Schmidt. 2005. Monitoring distributions using call surveys: estimating site occupancy, detection probability and inferring absence. Biological Conservation 123: 27-35.

Roble, S. M. 2003. *Rana sphenocephala* (Southern Leopard Frog). Catesbeiana 23: 21-24.

Saenz, D., L. A. Fitzgerald, K. A. Baum, & R. N. Conner. 2006. Abiotic correlates of anuran calling phenology: the importance of rain, temperature, and season. Herpetological Monographs 20: 64-82.

Steelman, C. K., & M. E. Dorcas. 2010. Anuran calling survey optimization: developing and testing predictive models of anuran calling activity. Journal of Herpetology 44: 61-68.

Stevens, C. E., A. W. Diamond, & T. S. Gabor. 2002. Anuran call surveys on small wetlands in Prince Edward Island, Canada restored by dredging of sediments. Wetlands 22: 90-99.

Todd, J. M., R. R. Cocklin, & M. E. Dorcas. 2003. Temporal and spatial variation of anuran calling activity in the western piedmont of North Carolina. Journal of the North Carolina Academy of Science 119: 103-110.

Tupper, T. A., & R. P. Cook. 2008. Habitat variables influencing a northern clade of *Bufo fowleri*: implications for conservation. Applied Herpetology 5: 101-119.

Tupper, T. A., R. P. Cook, B. C. Timm, & A. Goodstine. 2007. Improving call surveys for detecting Fowler's Toad, *Bufo fowleri*, in southern New England. Applied Herpetology 4: 245-259.

Varhegyi, G., S. M. Mavroids, B. M. Walton, C. A. Conway, & A. R. Gibson. 1998. Amphibian surveys in the Cuyahoga Valley National Recreation Area. Pp. 137-154 *In* M. J. Lanoo (ed.), Status and Conservation of Midwestern Amphibians. University of Iowa Press, Iowa City, IA.

Weir, L. A., & M. J. Mossman. 2005. North American Amphibian Monitoring Program (NAAMP). Pp. 307–313 *In* M. J. Lannoo (ed.), Amphibian Declines: The Conservation Status of United States Species. University of California Press, Berkeley, CA.

Weir, L. A., J. A. Royle, P. Nanjappa, & R. E. Jung. 2005. Modeling anuran detection and site occupancy on

North American Amphibian Monitoring Program (NAAMP) routes in Maryland. Journal of Herpetology 39: 627-639.

Wells, K. D. 1977. Territoriality and male mating success in the Green Frog (*Rana clamitans*). Ecology 58: 750-762.

Wiewandt, T. A. 1969. Vocalization, aggressive behavior, and territoriality in the Bullfrog, *Rana catesbeiana.* Copeia 1969: 276-285.

Wright, A. H. 1914. North American Anura: Life-Histories of the Anura of Ithaca, New York. Carnegie Institution of Washington, Washington, DC. 98 pp.

Wright, A. H., & A. A. Wright. 1949. Handbook of Frogs and Toads of the United States and Canada.Cornell University Press, Ithaca, NY. 640 pp.

Zar, J. H. 1999. Biostatistical Analysis. 4th Edition. Prentice Hall, New York, NY. 929 pp.

Banisteria, Number 39, pages 46-50

Survey and Assessment of Man-made Structures Used by Rafinesque's Big-eared Bats (*Corynorhinus rafinesquii*) in Southeastern Virginia

Leeanna T. Pletcher[1] and John D. Kleopfer

Virginia Department of Game and Inland Fisheries
3801 John Tyler Memorial Highway
Charles City, Virginia 23030

ABSTRACT

The distribution and abundance of Rafinesque's Big-eared Bat, a state-endangered species in Virginia, were investigated in 2008 by surveying previously documented and undocumented man-made structures. Of the 94 previously documented sites or structures inhabited by this species, 23 were confirmed to be in good status and 15 of these had bats present. Fourteen structures had been destroyed since 2002, 29 structures were known to have been destroyed prior to 2002, the status of seven structures was deemed vulnerable and the fate of 21 sites or structures was unknown,. Four active nursery colonies, each containing 30 to 50 females and their young, and 11 solitary roosts were documented during this study. Approximately 200 individuals were observed, mostly in Southampton and Sussex counties and the City of Virginia Beach. The overall population status in Virginia is unknown. Continued publicity and education are needed to enlist landowner cooperation and to locate other bat roosts.

Key words: Rafinesque's Big-eared Bat, distribution, Virginia.

INTRODUCTION

Rafinesque's Big-eared Bat (*Corynorhinus rafinesquii*) is classified as a state endangered species (as *C. rafinesquii macrotis*, the Eastern Big-eared Bat) in the Commonwealth of Virginia (VDGIF, 2005). The Virginia Department of Game and Inland Fisheries' (VDGIF) Comprehensive Wildlife Conservation Strategy ranks *C. rafinesquii* as a Tier I Species of Greatest Conservation Need (VDGIF, 2005). The Virginia Endangered Species Recovery Plan for the Eastern Big-Eared Bat outlines many recovery needs and strategies for this species (Schwab et al., 1990). The first goal of the Recovery Plan is to determine the distribution of *C. rafinesquii* in Virginia by searching man-made and natural roost sites for day-roosting

[1]Corresponding author: leeannapletcher@gmail.com