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## RESEARCH ARTICLE

# UTILIZING ACOUSTIC RECORDERS TO MONITOR ANURAN POPULATIONS ACROSS SOUTHERN MARYLAND AND VIRGINIA'S NORTHERN NECK

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## ABSTRACT

The main objectives of the acoustic recorder project were to monitor frog populations to describe local species diversity and find rare and endangered species. Other objectives were to expand local FrogWatch sites and to work with students to participate in fieldwork. Ten acoustic recorders were deployed across Southern Maryland and the Northern Neck of Virginia near different wetland habitats such as: swamps, marshes, vernal pools, ponds, and creeks. The recordings occurred from early March to the end of August 2025. In total, 11 species of anurans were recorded including *Scaphiopus holbrookii* (Harlan, 1835) (eastern spadefoot) which is a Virginia Department of Wildlife Resources Tier IVc species with Virginia's Wildlife Action Plan. Future surveys should be able to uncover more species in Maryland and Virginia including imperiled species like *Lithobates virgatipes* (Cope, 1891) (carpenter frog) and *Gastrophryne carolinensis* (Holbrook, 1835) (eastern narrow-mouthed toad).

**Keywords:** Citizen science, Kaleidoscope, *Scaphiopus holbrookii*, song meter, wildlife acoustics.

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## INTRODUCTION

Amphibians have been declining at an alarming rate and are doing so faster than any vertebrate class (Stuart et al., 2004). Monitoring amphibian populations is integral for the conservation and management of those species (Brodie et al., 2020). A large benefit to surveying frogs is that they call to attract mates whereas other amphibians are silent which can make tracking and sampling more difficult. There are citizen science programs that have tracked frog populations such as the North American Amphibian Monitoring Program (NAAMP) that ran from 1994-2015 and FrogWatch USA that started in 1998 and is still running. Other ways to document anurans can be through conducting herpetological field surveys (e.g., visual encounters, cover object

monitoring, roving auditory surveys) and acoustic monitoring. Acoustic monitoring is a way to collect auditory sounds from animals by placing a recording device in a specific animal's habitat; this has been used in a variety of taxa including birds, bats, and frogs. One benefit to acoustic monitoring studies is that they are non-invasive and can be done without entering sensitive habitat areas (Measey et al., 2017). Another benefit to using sound recorders is that once they are installed, recorders can monitor wildlife over long periods of time without an observer present (Brodie et al., 2022). This in turn can save a lot of time and staff resources. Acoustic monitoring can be used to estimate population sizes (Measey et al., 2017), track breeding phenology (Larsen et al., 2021) and help document the presence or absence of species (Brodie et al., 2020).

The main objectives of this acoustic recorder project were to monitor anuran populations to describe local species diversity and find rare and endangered species across Southern Maryland and the Northern Neck of Virginia. Other objectives were to expand local FrogWatch sites and to work with students to participate in fieldwork. Southern Maryland is the northern end of the range for *Lithobates virgatipes* (Cope, 1891) (carpenter frog) and *Gastrophryne carolinensis* (Holbrook, 1835) (eastern narrow-mouthed toad). *Lithobates virgatipes* is a S3 watchlist species in Maryland and a Virginia Department of Wildlife Resources (VDWR) Tier IIIa species. A Maryland S3 watch list species is vulnerable and has a moderate risk of extinction with around 21-80 known populations statewide. *Lithobates virgatipes* has 50 known breeding ponds – all of which are on the Eastern Shore (Cunningham & Nazdrowicz, 2018). A Virginia Tier IIIa ranking equates to a high conservation need with on the ground strategies in place for conservation. *Gastrophryne carolinensis* is state endangered in Maryland. Historically *L. virgatipes* and *G. carolinensis* were encountered in a wider area than they are now in Southern Maryland (Cunningham & Nazdrowicz, 2018). This study was hoping to uncover historical or additional populations of those species.

The Northern Neck is an under-surveyed area in Virginia where herpetological records are less than other neighboring areas (Greenlee, 2001). When looking at neighboring counties in the Virginia Fish and Wildlife Information Service (VaFWIS) database, there are many species of herpetofauna that are likely to be found (VaFWIS, 2025). The Southeastern King George Survey was conducted with the Virginia Herpetological Society (VHS) in hopes of finding additional county records and utilized an acoustic recorder in hopes to accomplish this (Neff, 2025).

Another goal from this study was to expand local FrogWatch chapter observation stations. FrogWatch USA is a citizen science program that monitors the breeding calls of frogs across the United States and is run by local chapters. The Southern Maryland (and surrounding DMV) chapter is run by the Calvert Marine Museum (CMM) and Calvert County Parks and Recreation since 2023. The chapter started as the National Zoo Chapter in 2013. To date there have been 86 observers that have submitted data into FrogWatch's database (hosted by Fieldscope) across Virginia, Maryland, District of Columbia, and West Virginia (FrogWatch, 2025). Selections of the acoustic recorder data from this study were also entered into the database. Since the chapter hosts are in Calvert County, Maryland, there were not a lot of observations from St. Mary's or Charles Counties. Educational outreach programs in those counties, as well as installing recorders across Southern Maryland, helped expand FrogWatch across the region.

## MATERIALS AND METHODS

The study began in early March with six acoustic recorders (Wildlife Acoustics Song Meter SM4). The first recorder was deployed on 14 March 2025 at the CMM. The dates for the other sites were staggered to coincide with educational programming. An additional four recorders

(Wildlife Acoustics Sound Meter Micro) were obtained in June and installed shortly after, see Figure 1 for locations, again staggered to coincide with program dates. The site names, site abbreviations, and installation dates can be viewed in Table 1. The recorders were all retrieved at the end of the frog calling season, 31 August 2025.



**Figure 1.** A map showing the 10 sites where acoustic recorders were placed.

The schedule for recording frog calls was 5 minutes every hour. After downloading the data, at the end of the season, calls were selected following NAAMP protocols (Foreman et al., 2017) – starting 30 minutes after sunset until 0100 hours the next morning.

Sounds were then processed through Kaleidoscope Pro from Wildlife Acoustics which is a sound analysis program for birds, anurans, and bats. Known frog sounds were pulled from the recorders and used to “bait” the program to group similar frequencies together in “clusters”. The user can then peruse through the files that were grouped together visually or auditorily to ensure they were correctly labelled. Sometimes sounds with similar frequencies were incorrectly grouped together with frog calls. The user could visually determine whether the sound was accurate since frogs would produce unique sound structures (Fig. 2). The user could also confirm auditorily, but this takes longer.

Also, weather information (e.g., temperature, precipitation, wind, and 48-hour history) was collected for the sites through Weather Underground. Data was collected every four days from the deployment date of each recorder. This information was used for data entry into Fieldscope for the citizen science program FrogWatch USA.

## RESULTS

There were a total of 28,836 5-minute sound files recorded. After processing the data, it was determined that 11 species of frogs and toads were recorded across the 10 sites. The common

and scientific names below and throughout the paper adhere to the Society for the Study of Amphibians and Reptiles (SSAR) Committee on Standard English and Scientific Names (Nicholson, 2025).

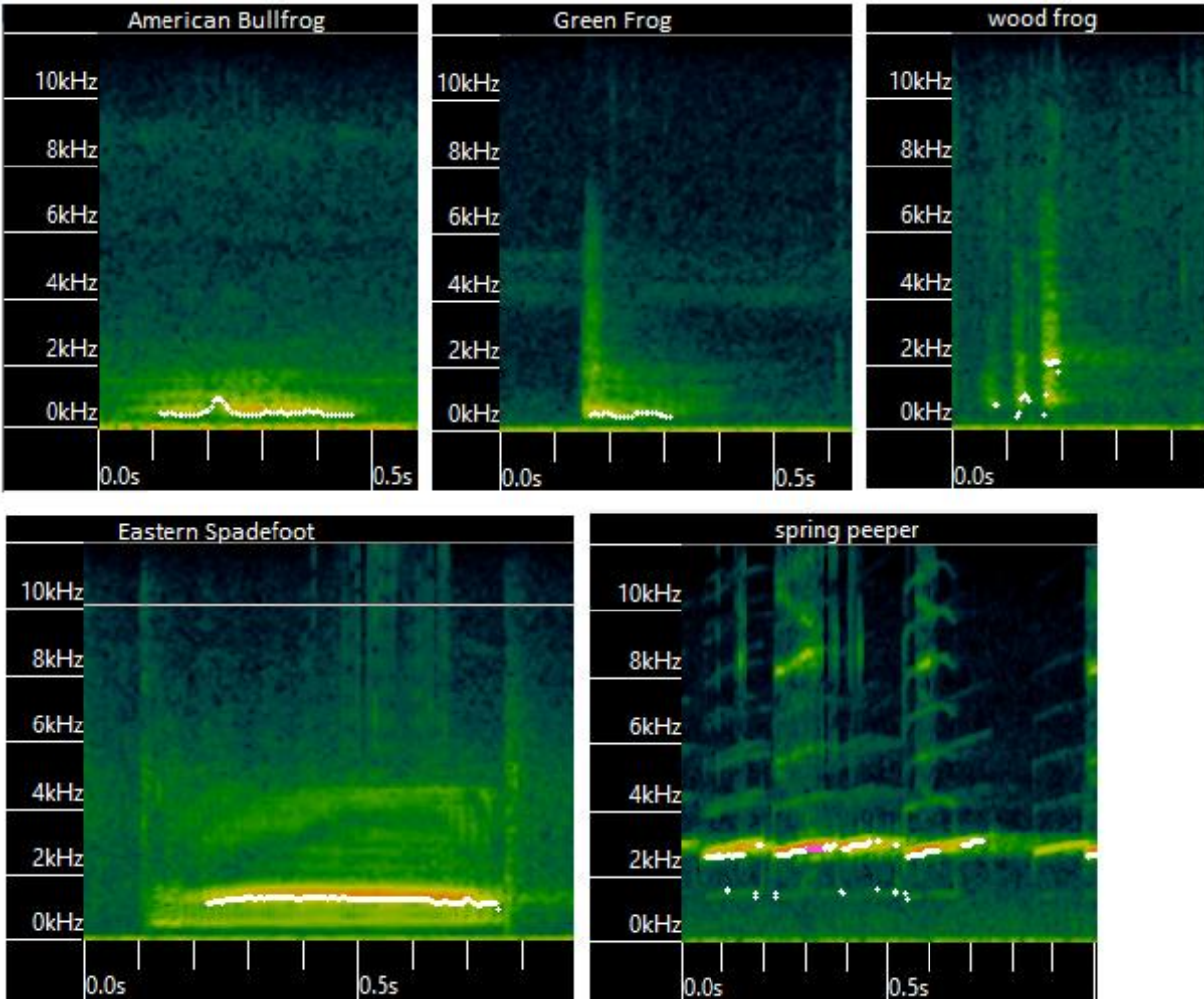
**Table 1.** List of sites and date ranges acoustic recorders were deployed.

Site No.	Location	Site Acronym	Installation Date Range (2025)
1	American Chestnut Land Trust	ACLT	16 March – 31 July
2	Calvert Marine Museum	CMM	14 March – 15 July
3	James A. Forest Career and Technology Center	JAFCTC	16 March – 16 July
4	Maryland Wildlife Management Area 1	MWMA1	11 April – 12 August
5	Maryland Wildlife Management Area 2	MWMA2	9 June – 9 July
6	Nanjemoy Creek Environmental Education Center	NCEEC	27 March – 9 August
7	Naval Air Station Patuxent River 1	PAX1	3 June – 15 July
8	Naval Air Station Patuxent River 2	PAX2	3 June – 24 July
9	Rappahannock River National Wildlife Refuge	RRNWR	7 June – 14 July
10	St. Mary's College of Maryland	SMCM	20 March – 5 August

The 11 species of anurans were: *Acris crepitans* Baird, 1854 (eastern cricket frog), *Anaxyrus a. americanus* (Holbrook, 1836) (eastern American toad), *Anaxyrus fowleri* (Hinckley, 1882) (Fowler's toad), *Dryophytes chrysoscelis* (Cope, 1880) (Cope's gray treefrog), *Dryophytes cinereus* (Schneider, 1799) (green treefrog), *Lithobates catesbeianus* (Shaw, 1802) (North American bullfrog), *Lithobates clamitans* (Latreille, 1801) (North American green frog), *Lithobates sphenoccephalus utricularius* (Cope, 1889) (coastal plains leopard frog), *Lithobates sylvaticus* (Le Conte, 1825) (wood frog), *Pseudacris crucifer* (Wied-Neuwied, 1838) (spring peeper), and *Scaphiopus holbrookii* (Harlan, 1835) (eastern spadefoot). See Table 2 for the sites each species was recorded.

The site that had the most anuran species abundance was NCEEC with seven species recorded. The sites with the least anuran species abundance were CMM and PAX2 – both with only one species recorded. The most abundant frog species were *D. chrysoscelis* and *L. clamitans* which were both encountered at 8 of the 10 sites. The least encountered anuran was *A. a. americanus* which was only recorded at NCEEC. The only rare species detected was *S. holbrookii*, a VDWR Tier IVc species, which was detected at RRNWR in Virginia. Also, the recorder installed at RRNWR recorded *D. cinereus* that was not encountered during the VHS survey on 7 June 2025.

Selections of this data were also entered into the Fieldscope database for the Southern Maryland (and surrounding DMV) FrogWatch chapter. Using data from all 10 sites, 456 additional FrogWatch observations were submitted for 2025.



**Figure 2.** Pictures showing the difference in frequencies that of some of the anurans produced in Kaleidoscope.

## DISCUSSION

In total, 11 species of frogs were recorded across 10 sites. When comparing this data to the Southern Maryland (and surrounding DMV) FrogWatch chapter database, where 14 species were recorded across 48 sites in 2025, 3 species were absent: *Dryophytes versicolor* (Le Conte, 1825) (gray treefrog), *Lithobates palustris* (Le Conte, 1825) (pickerel frog), and *Pseudacris feriarum* (Baird, 1854) (upland chorus frog) (FrogWatch, 2025). *Dryophytes versicolor* is not usually found in Southern Maryland (Hildebrand, W. G. 2005b) or the Northern Neck of Virginia (VHS, 2025), but *L. palustris* and *P. feriarum* are.

It is mentioned that *P. feriarum* calling activity is not just limited to the nighttime (Cunningham & Nazdrowicz, 2018) so this could be a factor why they weren't picked up on the recorders. Additionally, urban sprawl and other human-related activities could be a factor. During the MARA study from 2010-2014, although there was decent documentation of *P. feriarum* across St. Mary's County, in other areas it was noted that there has been decline from previous surveys (Cunningham & Nazdrowicz, 2018). Also, looking at previous FrogWatch data from 2023-2025 (when the chapter expanded to Southern Maryland), out of 3,053 observations, *P. feriarum* were

only recorded 10 times across six sites in Fairfax and Loudoun Counties in Virginia and Calvert, Montgomery, and St. Mary’s Counties in Maryland from 15 March – 26 April (Frogwatch, 2025). More in-depth studies across the region can determine if this species truly is declining. Furthermore, although FrogWatch follows NAAMP protocols, maybe these should be adjusted to capture data from anurans that call outside of the scotoperiod.

**Table 2.** Anuran species that were detected at each site.

Species/ Site Number	1	2	3	4	5	6	7	8	9	10
<i>Acris crepitans</i>				X	X					
<i>Anaxyrus a. americanus</i>						X				
<i>Anaxyrus fowleri</i>						X		X		
<i>Dryophytes chrysoscelis</i>	X		X	X	X		X	X	X	X
<i>Dryophytes cinereus</i>				X		X		X	X	
<i>Lithobates catesbeianus</i>		X		X	X			X		X
<i>Lithobates clamitans</i>	X		X	X	X	X		X	X	X
<i>Lithobates sphenoccephalus utricularius</i>			X		X	X				
<i>Lithobates sylvaticus</i>	X		X							
<i>Pseudacris crucifer</i>	X		X	X		X				
<i>Scaphiopus holbrookii</i>	X		X			X			X	X

The reason *L. palustris* was not found with the recorders is another story since they are more widespread and aren’t as vulnerable to human disturbance as *P. feriarum* (Cunningham & Nazdrowicz, 2018). Although two *L. palustris* were encountered during the VHS survey in Virginia (Neff, 2025), the recorder was installed at the end of their breeding range for the area – from March to June (Hildebrand, 2005b). Using the same 2023-2025 FrogWatch data as above, *L. palustris* was observed 116 times across 22 sites in Fairfax and Prince William Counties in Virginia and Anne Arundel, Calvert, Frederick, Montgomery, St. Mary’s Counties in Maryland from 5 March – 29 May (FrogWatch, 2025). *Lithobates palustris* has a lower frequency call than other species and cannot be heard at a distance (Hildebrand, 2005b), for this reason they may not be as easily observed in the field or could be drowned out by higher-pitched callers, like *P. crucifer*, and not picked up by the recorders or surveyors. Additionally, in more detail below, the recorders will be deployed 1 Feb 2026 next year to fully capture the anuran species that inhabit the area.

The only species of anuran detected during the study that was rare was *S. holbrookii* which is a VDWR Tier IVc species. A Tier IVc ranking equates to a moderate conservation need with no current on the ground conservation actions. *Gastrophryne carolinensis* and *L. virgatipes* have never been found in large numbers in Southern Maryland, but this study hoped to uncover historical or additional populations of these two species.

*Gastrophryne carolinensis* was first discovered in Maryland in 1936 in Calvert County (Noble & Hassler, 1936) and was last seen in Calvert in the 1970’s (Hardy, 1972). Their population declined in Southern Maryland due to habitat loss from development and they are currently only known to exist in St. Mary’s County (Cunningham & Nazdrowicz, 2018). There have been

anecdotal reports of *G. carolinensis* being heard in the general vicinity of its historical Calvert range in the 1990's (Caroline Seitz, Virginia Herpetological Society, personal communication) and 2010's (Jason Avery, Calvert County naturalist, personal communication). There was also an observation in Charles County in 2003, but it has not been verified (Hildebrand, 2005b).

*Lithobates virgatipes* was first discovered in Southern Maryland in the 1950's in Charles County (Reed, 1957). However, they have been rarely seen in Southern Maryland since then (Cunningham & Nazdrowicz, 2018). There have been unverified reports from Charles County in 2003 (Hildebrand, 2005b) and St. Mary's County in 2005 (Hildebrand, 2005a) and 2010-2014 during the Maryland Amphibian and Reptile Atlas (MARA) surveys (Cunningham & Nazdrowicz, 2018). Carpenter frogs prefer more acidic waters, more than other local frog species can tolerate, and are usually not found in areas with less acidic waters (Otto et al., 2007). Forest cover is important as detritus can help maintain acidic conditions as well as trees soaking up excess water and run-off. For this reason, disturbed and urbanized habitats with excess run-off limit the acidic habitat this frog needs to survive (Hildebrand, 2005b).

Another objective to this study was to increase the records of herpetofauna from the Northern Neck of Virginia. The Northern Neck is made up of five counties (west to east): King George, Westmoreland, Richmond, Northumberland, and Lancaster. King George has 51 documented species of herpetofauna, Westmoreland County has 58, Richmond has 45, Northumberland has 45, and Lancaster has 53 (VHS, 2025). These counties could have as many as 62 species of amphibians and reptiles based on species found in surrounding counties (VaFWIS, 2025). The Southeast King George survey was conducted at Land's End Wildlife Management Area and the Toby's Point Unit of the Rappahannock River National Wildlife Refuge in hopes of documenting potential anuran records for King George County: *G. carolinensis*, *L. virgatipes*, and *P. feriarum* (VHS, 2025). *Dryophytes femoralis* (Daudin, 1800) (pine woods treefrog) and *Pseudacris brimleyi* Brandt & Walker, 1933 (Brimley's chorus frog) are found in adjacent counties, but were not likely in King George (VaFWIS, 2025). Both *D. femoralis* and *P. brimleyi* are southeastern species where Southeastern and Southcentral Virginia is the northern extent of their ranges. *Dryophytes femoralis* is found in Southern Caroline County and Southeastern Essex County (VaFWIS, 2025), both to the south and southeast of King George respectively. While it could be possible for *D. femoralis* to be found, it would be a range extension since the aforementioned locations are the northern extent of its current range. Historically there was a record of *D. femoralis* as far north as Calvert County, Maryland (Fowler & Orton, 1947). That record had been scrutinized and after 84 years of repeated attempts to locate the species, it was determined to be a mistaken record (Miller, 2021). Similarly, with *P. brimleyi*, Southern Caroline County is the northern extent of its range (VaFWIS, 2025). While it is certainly possible for *P. brimleyi* to be found in Southeastern King George, it would be a range extension. While no new county anuran records were found during the survey, the acoustic recorder set up at RRNWR did record several choruses of *D. cinereus* 7 June – 5 July. *Dryophytes cinereus* was a species that was not encountered during the survey (Neff, 2025). Additional surveys across the Northern Neck are ongoing and different sites could uncover more species.

Additionally, data from this project was entered as observations for the Southern Maryland (and surrounding DMV) FrogWatch chapter. A high school student, pursuing a career in biology and marine sciences, helped enter weather data from selected dates from all 10 sites. Observations were entered into FrogWatch's nation-wide database hosted by Fieldscope. Since 2013, 5,427 observations have been submitted by the Southern Maryland (and surrounding DMV) chapter – 807 of which were this year (FrogWatch, 2025). From this study an additional 456 observations

were submitted. This brought the total observations for the chapter up to 1,263 this year – the most active year for the chapter to date.

Although there were a few setbacks with data collection and learning the sound analysis program, next year will be stronger. Firstly, the start of the grant award was later than the beginning of the frog calling season, so recorders were not placed until after March. This is approximately six weeks after the start of the frog calling season (Foreman et al., 2017). Additionally, batteries died in all 10 recorders before being collected at the end of the season. Start and end dates of all recorders can be viewed in Table 1. In the future, calls will be recorded with less frequency to help conserve battery life – recorders will start 30 minutes after sunset and record for 5 minutes every hour until 0100 hours. In testing this method over the fall and winter, the battery life in the Sound Meter Micros lasted 5 times longer than the method used during this study. Next season, the recorders will be installed 1 February 2026 – 31 August 2026, following NAAMP and FrogWatch protocols, and should be able to record all season in 2026. Also, learning how to work with the software to analyze the recordings took a few days to perfect. Sometimes sounds with similar frequencies were grouped together (e.g., American toad with an ambulance or green frog with a dog barking). Having to go through and verify if frogs were truly heard took longer than anticipated.

This program will be expanding next season through an additional grant and partners. An acoustic recorder will be lent from Battle Creek Cypress Swamp (Calvert County Parks and Recreation) and a site will be selected on grounds there. This program will also be partnering with the Cove Point Natural Heritage Trust (CPNHT) to receive 6 additional recorders to place in Calvert County and sites in Virginia. CHESPAX, Calvert County Public Schools' environmental education program, has extended the use of their recorders that were lent for this project until the end of 2026. In total, next season will have 18 sites monitored with the hope to find imperiled anuran species in Maryland and record new county records in Virginia's Northern Neck.

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Additionally, I would like to send a huge thanks to Tom Harten, a fellow herpetologist in Southern Maryland. Tom is an environmental educator with CHESPAX. Tom had extra acoustic recorders from a previous project with MARA and lent them to use for this program.

I would also like to thank the Calvert Marine Museum to allow me to participate in fieldwork to help describe local species diversity.

A colossal thanks goes to all the landowners for allowing me to survey their land. I was astounded by how enthusiastic everyone was to be a part of this project (alphabetical order by organization): Greg Bowen and Autumn Phillips-Lewis of the American Chestnut Land Trust (ACLT); Rachele Green at the Calvert Marine Museum; Chris Rowe at Chesapeake Biology Lab for allowing me to survey his sites at ACLT; Dorothy Birch at James A. Forest Career and Technology Center; Candice Collison, Katelyn Horn, and Beth Schlimm of Maryland Department of Natural Resources for allowing me to survey Maryland Wildlife Management Areas 1 and 2; Tim Emhoff and Mike Callahan at Nanjemoy Creek Environmental Education Center; Rebecca Stump at Naval Air Station Patuxent River; Bill Crouch of Eastern Virginia Rivers National

Wildlife Refuge Complex for surveying the Rappahannock River National Wildlife Refuge; and Barry Muchnick at St. Mary's College of Maryland.

Part of the data from this program was also used on the Virginia Herpetological Society's Southeastern King George Survey at Land's End Wildlife Management Area and Toby's Point Unit at the Rappahannock River National Wildlife Refuge in King George County, Virginia this past year. I would like to send a tremendous thanks to Bill Crouch, Deputy Refuge Manager of the Eastern Virginia Rivers National Wildlife Refuge Complex for allowing the VHS to survey through Special Use Permit #51622-25-R06. Bill was extremely helpful in pointing out areas to survey, additional areas to survey as backup, and to install an acoustic recorder through 31 August.

I would also like to thank to the Virginia Department of Wildlife Resources for allowing me and the VHS to survey through our Scientific Collection Permit #1672765.

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