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Natural Resource Stewardship and Science

Anuran Community Monitoring at Congaree National Park, 2011

Supplemental Monitoring to 2010 Efforts

Natural Resource Data Series NPS/SECN/NRDS—2013/527

ON THE COVER
Brimley's Chorus Frog (*Pseudacris brimleyi*)
Photograph by: Briana Smrekar

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Supplemental Monitoring to 2010 Efforts

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The National Park Service, Natural Resource Stewardship and Science office in Fort Collins, Colorado, publishes a range of reports that address natural resource topics. These reports are of interest and applicability to a broad audience in the National Park Service and others in natural resource management, including scientists, conservation and environmental constituencies, and the public.

The Natural Resource Data Series is intended for the timely release of basic data sets and data summaries. Care has been taken to assure accuracy of raw data values, but a thorough analysis and interpretation of the data has not been completed. Consequently, the initial analyses of data in this report are provisional and subject to change.

All manuscripts in the series receive the appropriate level of peer review to ensure that the information is scientifically credible, technically accurate, appropriately written for the intended audience, and designed and published in a professional manner. This report received informal peer review by subject-matter experts who were not directly involved in the collection, analysis, or reporting of the data.

This report is available in the Reports and Publications section of the Southeast Coast Inventory and Monitoring Network webpage (http://science.nature.nps.gov/im/units/secn/) and the Natural Resource Publications Management website (http://www.nature.nps.gov/publications/nrpm/). To receive this report in a format optimized for screen readers, please email irma@nps.gov.

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Executive Summary

The southeastern U.S. is host to one of the most diverse amphibian communities in the world. With an estimated 140 amphibian species, more than half of which are salamanders, the Southeast accounts for about half of the total number of amphibians in the U.S (Echternacht and Harris 1993, Petranka 1998). The Southeast Coast Network (SECN) has 61 known amphibian species; 26 in Caudata (salamanders, newts, amphiumas, sirens), and 35 in Anura (frogs and toads; Appendix A). Given their known population declines, sensitivity to anthropogenic stressors, and the diversity of amphibians in the southeastern U.S., amphibian communities are a priority for SECN monitoring efforts. This report summarizes a 2011 supplementary-monitoring effort of the vocal anuran community at Congaree National Park in follow-up to the 2010 amphibian community monitoring work conducted and summarized in Byrne et al. (2011).

- During 2011, automated recording devices (ARDs) were deployed to collect auditory information at a subset of 12 of the 2010 sampling locations at Congaree National Park.
- Auditory recordings were collected from 3/2/2011 through 5/27/2011.
- A total of 133 detections were made, where each detection represents an identifiable observation of a species or species group during one night of monitoring at a sampling location.
- We found 12 species of anurans.
- Spring peeper (*Pseudacris crucifer*) and Southern leopard frog (*Lithobates sphenocephalus)* had the highest frequency of occurrence at CONG in 2011. Southern chorus frog (*Pseudacris nigrita*) and bullfrog (*Lithobates catesbeianus*) had the lowest frequency of occurrence.
- The Southern leopard frog had the highest relative frequency of detection of anuran vocalizations on the automated recordings.
- Spring peeper and Southern leopard frog were the most widely distributed species during our 2011 monitoring efforts at this subset of sampling locations.
- No non-native species were found.
- Amphibian communities will next be sampled in 2014.
- The full dataset and associated metadata can be acquired from the NPS Integrated Resource Management Applications (IRMA) portal at http://irma.nps.gov.

Introduction

Overview

Amphibian populations have exhibited declines in North America and many other areas around the world. Several factors are attributable to population declines and localized extinctions. Among these factors are disease and anthropogenic stressors such as habitat loss and degradation, non-native predators, acid precipitation, altered hydrology and hydroperiod, ultraviolet radiation, and chemical contaminants (Collins and Storfer 2003). Although diseases and parasites naturally occur in amphibian populations, the effects of these influences can be exacerbated when combined with other anthropogenic stressors.

Amphibians have complex life cycles, where the immature phase often consists of an aquatic larval stage, followed by a post-metamorphic adult terrestrial stage. Slight alterations in the aquatic or terrestrial communities upon which amphibians are dependent can have substantial impacts on the survival, reproduction, and persistence of a species. Given their habitat requirements, anatomy, and physiology, amphibians are considered good indicators of ecological condition.

The southeastern U.S. is host to one of the most diverse amphibian communities in the world. With an estimated 140 amphibian species, more than half of which are salamanders, the Southeast accounts for about half of the total number of amphibians in the U.S (Echternacht and Harris 1993, Petranka 1998). The Southeast Coast Network (SECN) has 61 known amphibian species; 26 in Caudata (salamanders, newts, amphiumas, sirens), and 35 in Anura (frogs and toads; Appendix A).

Given their known population declines, sensitivity to anthropogenic stressors, and the diversity of amphibians in the southeastern U.S., amphibian communities are a priority for SECN monitoring efforts.

The National Park Service Omnibus Management Act of 1998, and other reinforcing policies and regulations, require park managers “to establish baseline information and to provide information on the long-term trends in the condition of National Park System resources” (Title II, Sec. 204). The amphibian-community monitoring data summarized herein is a tool to assist park managers in fulfilling this mandate.

Supplemental Monitoring

This report presents data collected as a part of the Southeast Coast Network Vital Signs Monitoring Program’s efforts to assess the status and trends of anuran communities at Congaree National Park. Specifically, this report summarizes a follow-up and supplementary anuran community monitoring effort in response to 2010 pilot-monitoring results (see Byrne et al. 2011) and is not intended to be a stand-alone, comprehensive report on the anuran community at CONG.

As part of the protocol-development process, the methodology implemented at CONG in 2010 consisted of monitoring the vocal anuran community four times over a 14-day period. Based upon the results of the pilot-protocol implemented at CONG and all other SECN parks from 2009-2010, and the ability of this variation of the method to meet the protocol objectives, the methodology was modified prior to the 2011 field season to collect data from 20 sampling events

over a 77-day period. The primary reasons for method modification were to (a) collect data over a wide range of temperature, relative humidity, and precipitation regimes (i.e., known influences on anuran vocalization initiation), (b) increase the likelihood of detecting species whose peak breeding does not occur in the spring (e.g., winter breeders), and (c) produce a more robust characterization of species distribution and occupancy.

As mentioned in Byrne et al. (2011), the 14-day monitoring window for vocal anurans in 2010 coincided with an atypically dry period. Consequently, few species were detected. Visual-encounter surveys conducted later in the 2010 season at all of the sampling locations detected many species that were likely present during the ARD survey window, but not detected due to the negative influence of the weather conditions on anuran vocalization initiation, and subsequent detection by the ARDs. Therefore, to ensure the amphibian community was adequately characterized, and to continue to test and evaluate the protocol, a supplemental sampling effort was warranted. Because of the other parks monitored in 2011 and their juxtaposition relative to CONG, and assistance from Park staff with retrieval of the ARDs, a repeat survey of a subset of sampling locations at CONG did not add any significant costs to this supplemental monitoring effort.

The intent of the supplemental monitoring effort was not to facilitate across-year comparisons, as this is not possible given the difference in the methods across the two years. Therefore, this report does not make comparisons among the 2010 and 2011 data, nor are the differences between the two ARD deployment regimes (i.e., 4 sampling events over 14 days, 20 sampling events over 77 days) evaluated. This report does, however, summarize and present data from the 2011 supplemental monitoring effort in the same manner as if the protocol were implemented in full.

Study Area

Congaree National Park is situated adjacent to the Congaree and Wateree Rivers in southeast Richland County, South Carolina, approximately 20 miles southeast and downstream of the capital Columbia (Figure 1). Encompassing 25,300 acres, the park protects old-growth trees and diverse plant and animal life within the largest intact expanse of old-growth bottomland hardwood forest remaining in the United States. Periodic flood waters from the adjacent rivers flow through the bottomland forest in winter and spring, carrying nutrients and sediments that nourish and rejuvenate this unique floodplain ecosystem. Nearly 90 species of trees grow within the park, with many that are recognized as national and state champions for their size. Forested wetlands, oxbow lakes, and slow moving creeks and sloughs provide habitat for fish, birds, reptiles, mammals and other aquatic life. The diversity of flora and fauna, tall tree canopy, champion trees, and intact floodplain ecosystem earned the park the designation of an International Biosphere Reserve, National Natural Landmark, Globally Important Bird Area, and Congressionally designated Wilderness Area.

A wide variety of forest communities are represented at CONG, with dominant tree species ranging from upland pines (*Pinus* spp.) to wetland cypress (*Taxodium* spp.) and tupelo (*Nyssa* spp.). The Congaree River floodplain is characterized by silty clay soils, oxbow lakes, swales and sloughs, and meandering creeks. The Congaree and Wateree Rivers are the major source of floodwaters, sediment, and nutrients delivered to the Park, although several tributary creeks are also present. The significance of CONG lies in its: (a) unique old-growth bottomland hardwood

forest community associated with the swamp-like floodplain, (b) large trees, including loblolly pine (*P. taeda*), bald cypress (*T. distichum*), tupelo, sweet gum (*Liquidambar styraciflua*), American sycamore (*Platanus occidentalis*), swamp cottonwood (*Populus heterophylla*), oak (*Quercus* spp.), and American holly (*Ilex opaca*); (c) the intact floodplain ecosystem, and (d) high biodiversity.

CONG has 23 known vocal Anuran species (Table A-1).

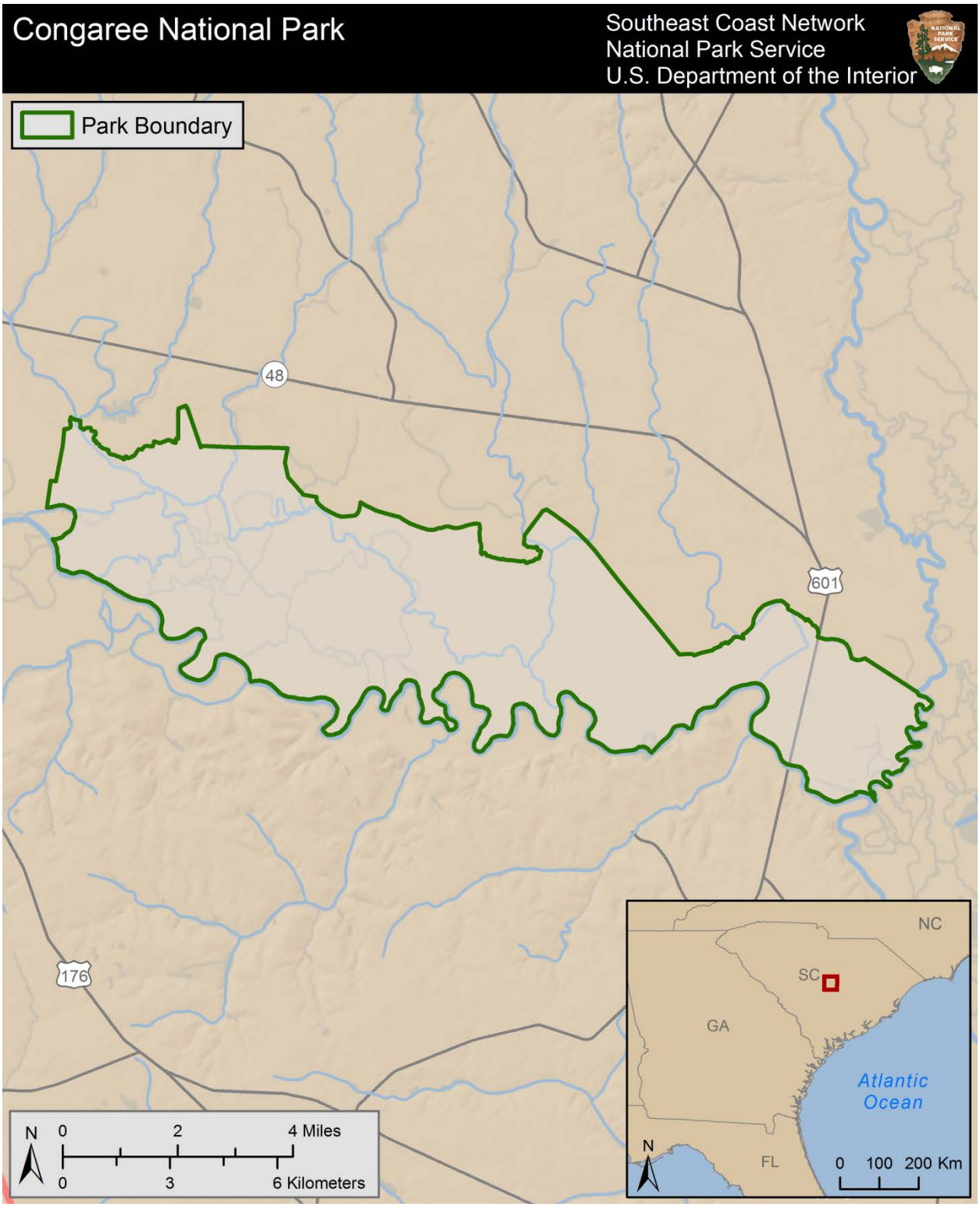

Figure 1. Location of Congaree National Park.

Environmental Setting During Sampling Event

Climatologically, the Southeastern U.S. experienced warmer than normal average temperatures throughout much of 2011, which was preceded by a winter season (December 2010-February 2011) with temperatures below normal or much below normal. Precipitation was well below average during much of the year, with conditions in the southeastern states rated as abnormally dry or in drought status (Wright 2012).

Based on data collected from the Columbia Metro Airport and the Congaree National Park weather stations, mean monthly temperatures were above average during the SECN amphibian monitoring time frame of March through May 2011 (Figure 2). However, temperatures were not outside the range of variation for the 30-year average. High temperatures ranged from 68.6°F to 85.8°F, while lows ranged from 44.5°F to 59.6°F during the sampling period (Wright 2012). Precipitation during the same period was at normal levels during the first part of the SECN sampling period. Average precipitation was below average during May, although not significantly different from the 30-year average for precipitation. Total annual precipitation averaged 7.96 inches below normal for the greater northern Columbia area, with the winter months having the lowest precipitation levels (Figure 3).

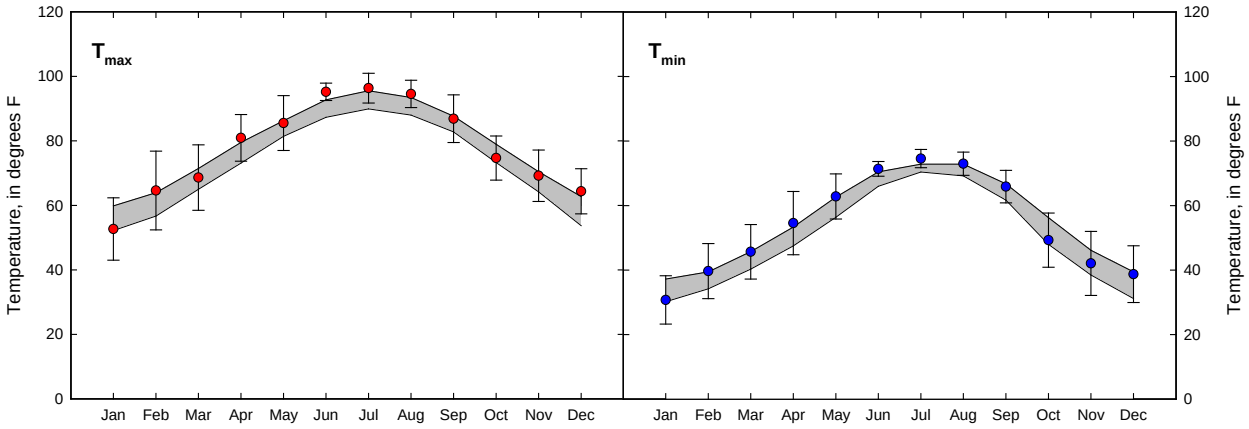

Figure 2. 2011 average monthly temperature and the 30-year (1981 – 2010) average for Columbia Metro Airport station. Units = °F. Points indicate the 2011 average monthly maximum and minimum temperatures. Error bars indicate +/- standard deviation. The dual solid lines bound the standard deviation around the 30-year (1981-2010) mean monthly temperature.

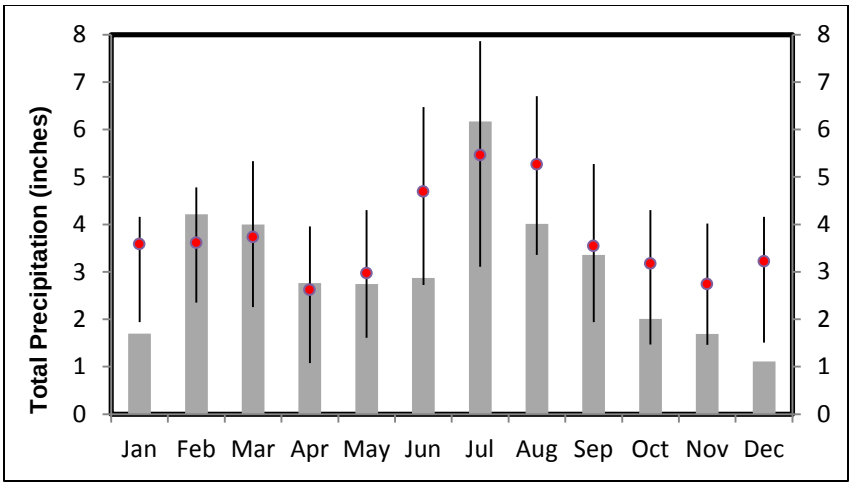

Figure 3. Total monthly precipitation during 2011 and the 30-year (1981 - 2010) monthly averages for Columbia Metro Airport station. The gray columns represent 2011 total monthly precipitation. The red circles represent the 30-year average; the lines indicate the 25th and 75th percentile of the 30-year normal data for each month.

Monitoring Objectives

Analysis of amphibian monitoring data is based on detections of vocal anurans using automated recording devices, where a detection is considered to be one or more observations of a species or species group during one night of monitoring at a sampling location. The SECN has four monitoring objectives related to amphibian communities based on post-metamorphic anuran vocalization data collected from March to mid-June in non-saline wetland and upland vegetation communities in all Southeast Coast Network parks (Byrne et al. 2013 *in review*).

- *Determine the status and trends in species richness and diversity of vocal anuran communities*. Species richness and diversity estimates are based on the total number of species detected (i.e., native and non-native).

- *Determine the status and trends in occupancy by vocal anuran species*. Occupancy estimates provide insight into the likelihood of encountering a specific species, rarity, diversity, and distribution of a species or group, and relative comparisons provide insight into the composition of the sample.

- *Determine the status and trends in frequency of detection of vocal anurans*. Frequency of detection is the number of nights a species or species group is observed during the sampling event at each sampling location.

- *Determine trends in the vocalization phenology of select anurans with high detectability*. Vocal anuran calling patterns of species with high detectability (i.e., an unbiased detectability estimated generated from the occupancy-modeling process) will be analyzed to determine the status and trends in the first and last dates on which species are detected.

Methods

Sampling Design

In 2010, to allow for park-wide inference, the CONG administrative boundary was used as the sampling frame, within which a spatially-balanced sample was drawn using the Reversed Randomized Quadrant-Recursive Raster (RRQRR) algorithm (Theobald et al. 2007). Amphibian communities were then sampled at 30 locations that met the selection criteria (i.e., safety and access considerations) as described in Byrne et al. (2013 *in review*). Because this was a supplemental sampling effort to 2010 monitoring, a subset of the original sampling locations were used.

Selection of sampling locations for the 2011 monitoring was based on three criteria; 1) anurans were detected at the location during the 2010 VESs, 2) species of management interest were previously detected or expected to occur, and 3) locations represented a relatively equal assemblage of sampling locations adjacent to various freshwater resource types (i.e., perennial, ephemeral).

Sampling locations were deemed suitable locations for redeployment if a number of anurans were detected during 2010 visual encounter surveys, but vocalizing anurans were noticeably absent during the recording period. Another factor in determining suitable redeployment locations was the presence of adult or larval stage anurans which were unidentifiable to species during out 2010 monitoring efforts. To satisfy criteria number two, locations were selected where several anuran species of monitoring or conservation interest were detected during 2010 monitoring activities. Specific anurans targeted in this ARD re-deployment effort were the pickerel frog (*Lithobates palustris*) and the Southeastern (upland) chorus frog (*Pseudacris feriarum*), because each is listed as a priority species of concern in South Carolina (SC Department of Natural Resources 2005). Locations with Brimley's chorus frog (*Pseudacris brimleyi*) were also targeted, due to its limited range on the Coastal Plain of the Eastern United States. Brimley's chorus frog is also a state listed species of concern in the neighboring state of Georgia (Dorcas and Gibbons 2008). Finally, because of the wide distribution of anurans across CONG, and variable species assemblages often linked to dispersal ability and breeding linkages to perennial or ephemeral water resources, we chose to redeploy in sampling locations across a wide range of vegetation community (i.e., amphibian habitat) types. Four of the locations were in close proximity to a deep, permanent water resource, five contained vernal pools or seasonally-inundated swamp areas, two were located in wooded upland locations, and one location occurred in a fallow field. The final suite of supplemental locations was widely distributed across the Park (Figure 4).

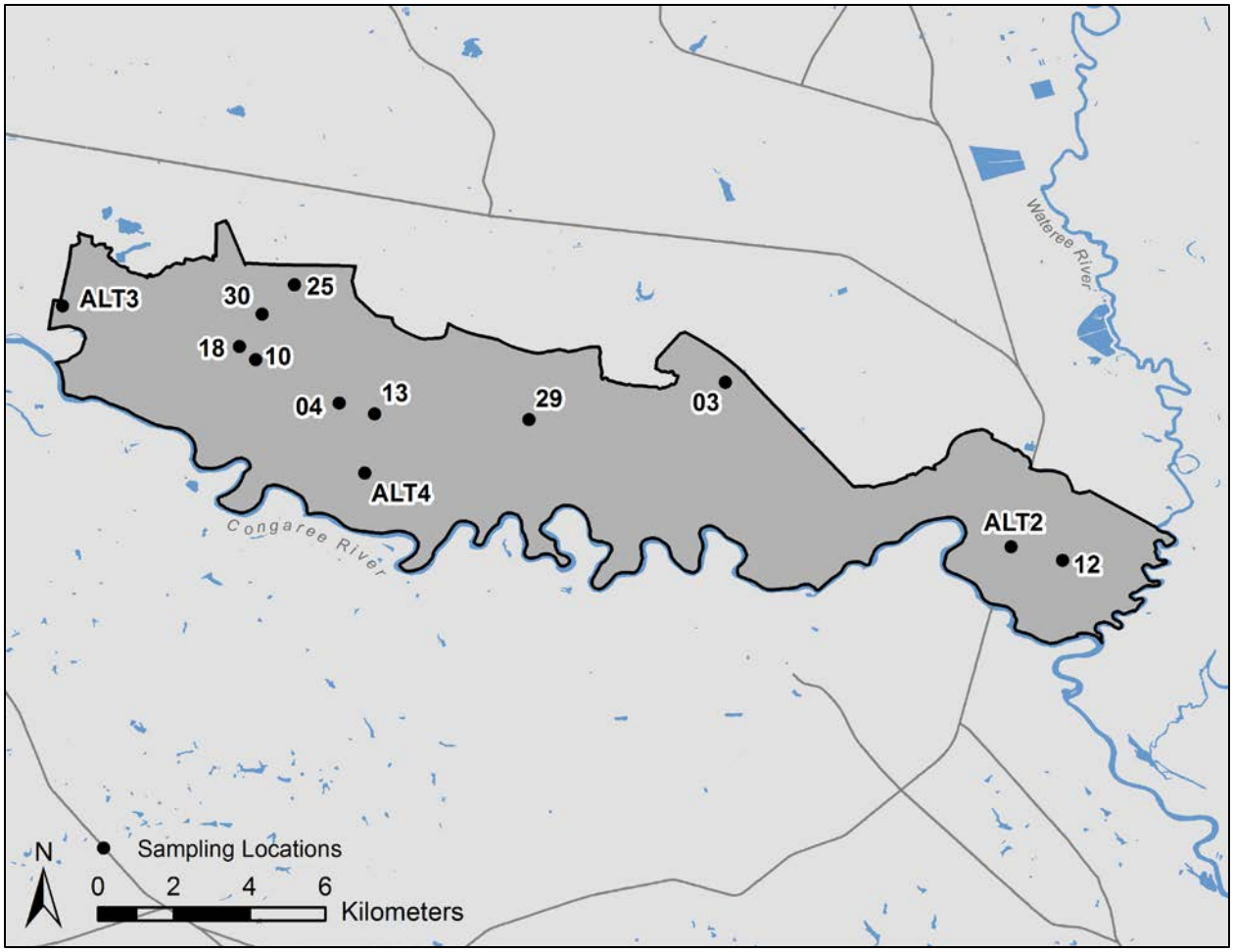

Figure 4. Select sampling locations for ARD redeployment at Congaree National Park, 2011.

Sampling Methodology

Automated-recording devices (ARDs) were used in this SECN amphibian monitoring methodology. The ARDs were deployed at each sampling location to record anuran vocalizations and adequately detect any species in a 0.5-ha macroplot. ARDs were programmed to record every four days from 20:00 (8:00 pm) to 06:50 am for 30 seconds of every 10 minutes.

Automated Recording Devices

Automated recording devices are often used to characterize soundscapes. Recently this technology has been applied to monitoring wildlife species. The use of ARDs is advantageous in SECN parks because of (a) the high number of vocal anurans (i.e., vocalizing frogs and toads) in SECN parks (i.e., 35), (b) many of these species are assumed to be broadly distributed across park lands, (c) crepuscular and nocturnal calling behavior predominates the vocal anurans in SECN parks (Mohr and Dorcas 1999, Bridges and Dorcas 2000, Todd et al. 2003), (d) night-time calling surveys are a concern given the safety issues for personnel conducting the surveys, and (e) the resultant detection/non-detection data of ARDs adheres to the monitoring objective. Further, the devices produce a permanent data product (i.e., recordings) that can be further analyzed as technology improves, analyzed by other researchers, analyzed for other taxa, or to quantify the soundscape.

To address some of the known influences related to imperfect detection (MacKenzie et al. 2002, MacKenzie et al. 2006), devices were deployed for a duration of 85 days to ensure detection of species present at the park as well as to assess changes in calling phenology. After the deployment period, the devices were retrieved and audio files were analyzed by SECN staff to determine the date, time, and species of all vocal anurans that were detected.

As is the case with all data collected with ARDs, the information derived is based on species' detectability. The occupancy estimates and phenology trends are based on methodology and data collection that does not account for environmental cues that initiate calling behavior (e.g., rainfall, humidity, and temperature). Additionally, while every effort is made to ensure that our recording timeframe is sufficient to encompass most vocalizing anurans, the recordings are only a portion of the time during which anurans are active. To adequately characterize the anuran community, we determined the most appropriate timeframe for deploying the ARDs in SECN parks to be March through June based on vocalization-phenology information (Dorcas and Gibbons 2008) and data from 2009-2012 recordings in National Park units across the SECN. The most appropriate anuran candidate species' vocalization dates are published in this report.

ARDs were deployed over 22 sampling events, from 3/2/2011 through 5/27/2011. A total of 8,547 minutes were recorded by all of the devices deployed at Congaree National Park. The ARD malfunctioned or was damaged in a storm and recorded partial data at two sampling locations (12 and 29). In 2010, ARDs were deployed over four sampling events, from 4/10/2010 to 4/27/2010 with a total of 3,168 minutes of recordings analyzed.

Data Analysis

This protocol collects detection / non-detection data, which, although somewhat inaccurately, is also often referred to as presence / absence data. In contrast to detections made from visual survey methods where individuals can be seen, differentiated, and counted detections from our other surveying method, automated recording devices, cannot be reliably associated with more than one individual. In general, one individual will vocalize multiple times during the survey period and is likely to be detected multiple times. Consequently, data-summary techniques do not equate one vocalization with one individual and analyses are conducted accordingly.

Taxonomic Standards

Despite a well-trained field crew, complete identification of all individuals encountered was not always possible. Species are, however identified to most refined taxonomic level possible. The majority of these species could be identified to the genus level based upon knowledge of the site and the local fauna.

Composition

Measures of community composition are often good indicators of abiotic variability, disturbance, or other stressors. Summaries related to composition include the total number of species detected (i.e., species richness), naïve occupancy, relative abundance, and relative detection frequency. Species richness is simply the number of native species detected. Naïve occupancy is the percentage of the sampling locations where a species was detected at least once, without adjusting for probability of detection. Naïve occupancy is also referred to as frequency of occurrence. Relative detection frequency uses the detection history as an index of abundance to communicate the composition of each species detected relative to all other species detected in the

sample. To minimize the bias inherent in this summary from the influences of detectability, vocalization behavior, sound properties, and various aspects of the automated analysis process, the estimate of relative detection frequency is derived by pooling across the detection histories and sampling locations for each species.

Distribution

Understanding changes in the distribution of amphibian species is integral to informed management of species and their requisite habitats. Changes in species distributions over time provide useful information at both the local and landscape scale relating to how species respond to large-scale influences such as changing land use, climate, hydrology, or habitat availability and condition. Shifting species distributions can produce cascading effects through altered species interactions and alterations within the food-web structure, thereby affecting ecosystem processes (Montoya and Raffaelli 2010). Distribution maps for all amphibian species encountered are presented in Appendix B.

Phenology

Phenology, the periodic life-cycle events of plants and animals as they are influenced by changes in the seasons, is an increasingly useful tool in monitoring climate change and its potential effects on amphibian populations (Blaustein et al. 2001, Gibbs and Breisch 2001, Corn 2005, Parmesan 2007, Blaustein et al. 2010, Todd et al. 2011). The timing of anuran territorial and mating vocalizations can provide insight into the initiation of the breeding season for these animals, and tracking these dates may prove to be a robust method for monitoring climate change, as it presents in the southeastern United States. The SECN reports the earliest and latest vocalization dates of select anuran species based on their known annual vocalization pattern, and the recording window of our methodology. Periodic synthesis reports, which will be published after multiple rounds of sampling, will summarize phenological history of amphibian species detected across the SECN for which appropriate candidates for trend analysis are available.

Findings

Community Composition

Species richness for our limited anuran sampling activities at CONG in 2011 was 12 species (Table 1). Detected species richness increased two-fold, compared to a species richness of just six species for this same subsample of locations during our 14 day ARD monitoring efforts in 2010 (Byrne et al. 2011). Six anuran species were detected at over one-quarter of the 2011 sampling locations, indicating high species diversity for our limited 2011 sampling efforts (Table 1). Six anuran species composed approximately 80% of the of the vocalization detections.

Spring peeper (*Pseudacris crucifer*) and Southern leopard frog (*Lithobates sphenocephalus*) detected at approximately 67% of the 2011 sampling locations, had the highest frequency of occurrence (naïve occupancy) of all anurans detected during our monitoring efforts (Table 1). Cope's gray treefrog (*Hyla chrysoscelis*) was detected at half of the locations, while Brimley's chorus frog (*Pseudacris brimleyi*) had a frequency of occurrence of just less than 42%. The Southern toad (*Anaxyrus terrestris*) was detected at one third of all 2011 sampling locations. The green treefrog (*Hyla cinerea*), Southern chorus frog (*Pseudacris nigrita*), and bullfrog (*Lithobates catesbeianus*) had the lowest frequency of occurrence across the selected sampling locations at CONG in 2011.

The Southern leopard frog had the highest relative detection frequency of vocalizations recorded by ARDs over the 85-day sampling period, followed by the spring peeper, Brimley's chorus frog, and Cope's gray treefrog (Figure 5). Nearly one quarter of all vocalizations detected in 2011 were attributed to the Southern leopard frog. Spring peeper vocalizations composed 18% of all vocalizations detected, while Brimley's chorus frog and Cope's gray treefrog accounted for 14% and 11% of all vocalizations detected, respectively. The bullfrog had the lowest relative detection frequency of vocalizations during the recording period. No non-native species were detected.

Table 1. Percentage of sampling locations where each anuran species was detected (i.e., naïve occupancy) using automated recording devices (ARDs) at Congaree National Park, 2011.

Species	% Locations
Spring Peeper	66.7
Southern Leopard Frog	66.7
Cope's Gray Treefrog	50.0
Brimley's Chorus Frog	41.7
Southern Toad	33.3
Green Frog	25.0
Southeastern (Upland) Chorus Frog	16.7
Pickerel Frog	16.7
Squirrel Treefrog	16.7
Southern Chorus Frog	8.3
Bullfrog	8.3
Green Treefrog	8.3
Total Sampling Locations	**12**

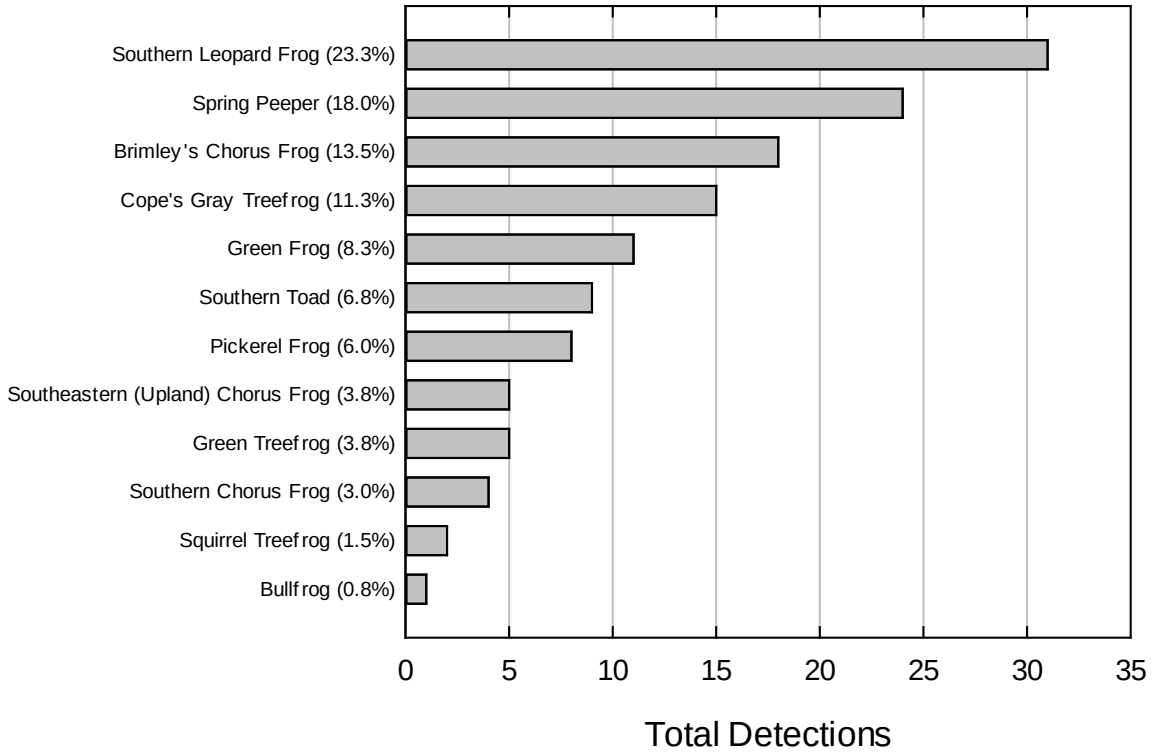

Figure 5. Number of anuran vocalization detections and the percent relative detection frequency (i.e., number of species vocalizations compared to all species' vocalizations) of recorded calls during automated recording device (ARD) deployment (3 March to 27 May 2011) at Congaree National Park. Based on n=133 detections.

New Species Records

All anuran species detected during the 2011 monitoring event at Congaree National Park were known to be on the park species list.

Amphibian Distribution

The spring peeper and Southern leopard frog were the most widely distributed species at CONG in 2011, found in multiple locations spanning the entire east to west expanse of the park (Table 1, Appendix B). Cope's gray treefrog and Southern toad were also detected spread across the park, but at fewer sampling locations. The Southern chorus frog and the bullfrog had the most limited distribution across CONG, detected in the western edge of the park at one location each. Species of conservation interest also had limited distributions during the 2011 monitoring effort. Pickerel frog was found at two locations, each near a permanent water resource, while the Southeastern (upland) chorus frog was detected only at sampling locations in the western half of the park. Brimley's chorus frog was detected at five of the 12 2011 locations, all but one of which were located in the central portion of the park. Distribution maps for all amphibians that were detected during the monitoring event are presented in Appendix B.

Vocalization Phenology

Of the anurans detected using ARDs at Congaree National Park in 2011, four species would be appropriate candidates to determine trends in vocalization start dates; green treefrog, Cope's gray treefrog, squirrel treefrog, and green frog. These species were considered appropriate candidates because they typically begin to vocalize well after the start of our recording schedule in the SECN parks (Dorcas and Gibbons, 2008). Cope's gray treefrog was first detected on 4/3/2011, while the green treefrog initiated vocalization on 4/20/2011. The green frog was first detected on 4/24/2011 and the squirrel treefrog had a first vocalization date of 4/27/2011 (Figure 6). One other species, the bullfrog, was only detected calling toward the end of the surveying period, call date of 5/21/2011. Four species were considered appropriate candidates for tracking end dates due to the timing of their typical vocalization windows in the Southeast, which usually close well before our recording schedule concludes (Dorcas and Gibbons, 2008). The Southern chorus frog, Brimley's chorus frog, and the pickerel frog were last detected using ARDs on 4/7/2011. The last detected vocalization for spring peeper was on 4/8/2011 at our sampling locations in CONG (Figure 6).

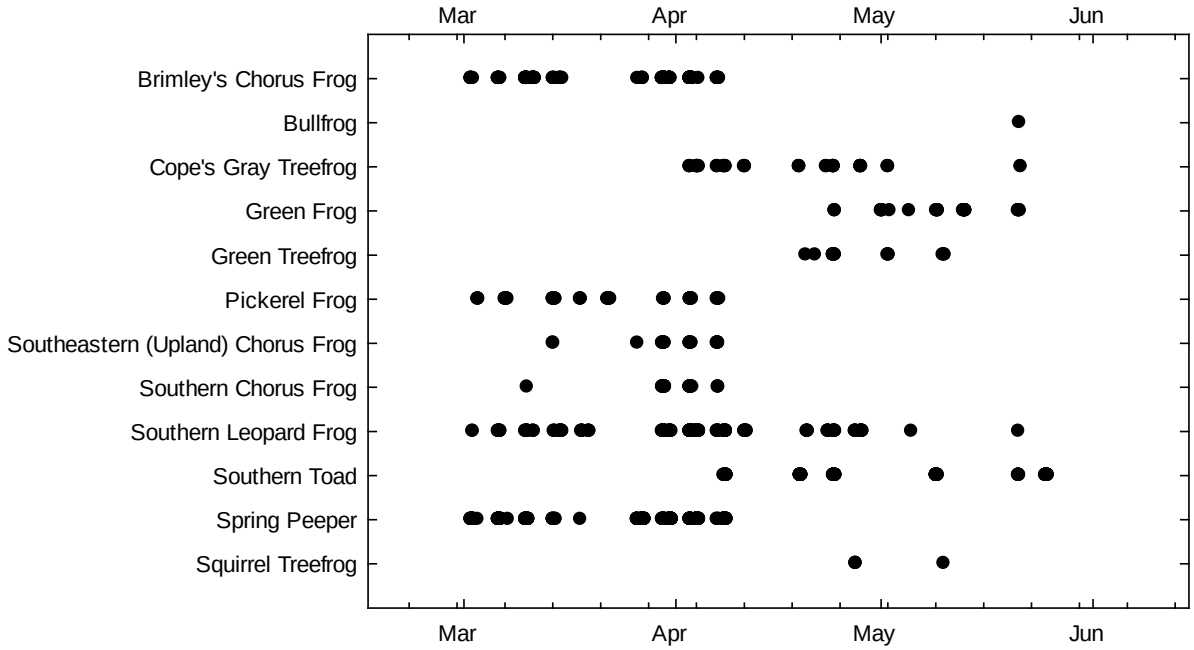

Figure 6. Vocalization phenology for species detected using automated recording devices (ARDs) at Congaree National Park, from 3 March to 27 May, 2011. Based on n=133 detections.

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Appendix A. Amphibian Species Detection Data

Table A-1. Anuran species known to occur at Congaree National Park based on the Park's certified species list (NPSpecies 2013) and those detected during this sampling effort.

Scientific Name	Common Name	NPSpecies	ARD
Anaxyrus terrestris	Southern Toad	X	X
Acris crepitans	Northern Cricket Frog	X	
Acris gryllus	Southern Cricket Frog	X	
Hyla chrysoscelis	Cope's Gray Treefrog	X	X
Hyla cinerea	Green Treefrog	X	X
Hyla femoralis	Pine Woods Treefrog	X	
Hyla gratiosa	Barking Treefrog	X	
Hyla squirella	Squirrel Treefrog	X	X
Hyla versicolor	Gray Treefrog	X	
Pseudacris brimleyi	Brimley's Chorus Frog	X	X
Pseudacris crucifer	Spring Peeper	X	X
Pseudacris feriarum	Southeastern (Upland) Chorus Frog	X	X
Pseudacris nigrita	Southern Chorus Frog	X	X
Pseudacris ornata	Ornate Chorus Frog	X	
Gastrophryne carolinensis	Eastern Narrow-mouthed Toad	X	
Scaphiopus holbrookii	Eastern Spadefoot	X	
Lithobates catesbeianus	Bullfrog	X	X
Lithobates clamitans	Green Frog	X	X
Lithobates clamitans clamitans	Bronze Frog	X	
Lithobates heckscheri	River Frog	X	
Lithobates palustris	Pickerel Frog	X	X
Lithobates sphenocephalus	Southern Leopard Frog	X	X
Lithobates virgatipes	Carpenter Frog	X	

Table A-2. Anuran species detected at each sampling location at Congaree National Park, 2011.

	Sampling Location											
Species	**3**	**4**	**10**	**12**	**13**	**18**	**25**	**29**	**30**	**Alt2**	**Alt3**	**Alt4**
Southern Toad	X		X						X	X		
Cope's Gray Treefrog	X	X	X							X	X	X
Green Treefrog		X								X		
Squirrel Treefrog				X								X
Brimley's Chorus Frog		X			X			X			X	X
Spring Peeper	X	X				X	X	X	X	X	X	X
Southeastern (Upland) Chorus Frog											X	X
Southern Chorus Frog											X	
Bullfrog									X			
Green Frog	X				X				X			
Pickerel Frog									X	X		
Southern Leopard Frog	X	X	X		X			X		X	X	X

Appendix B. Distribution Maps for Anuran Species Encountered

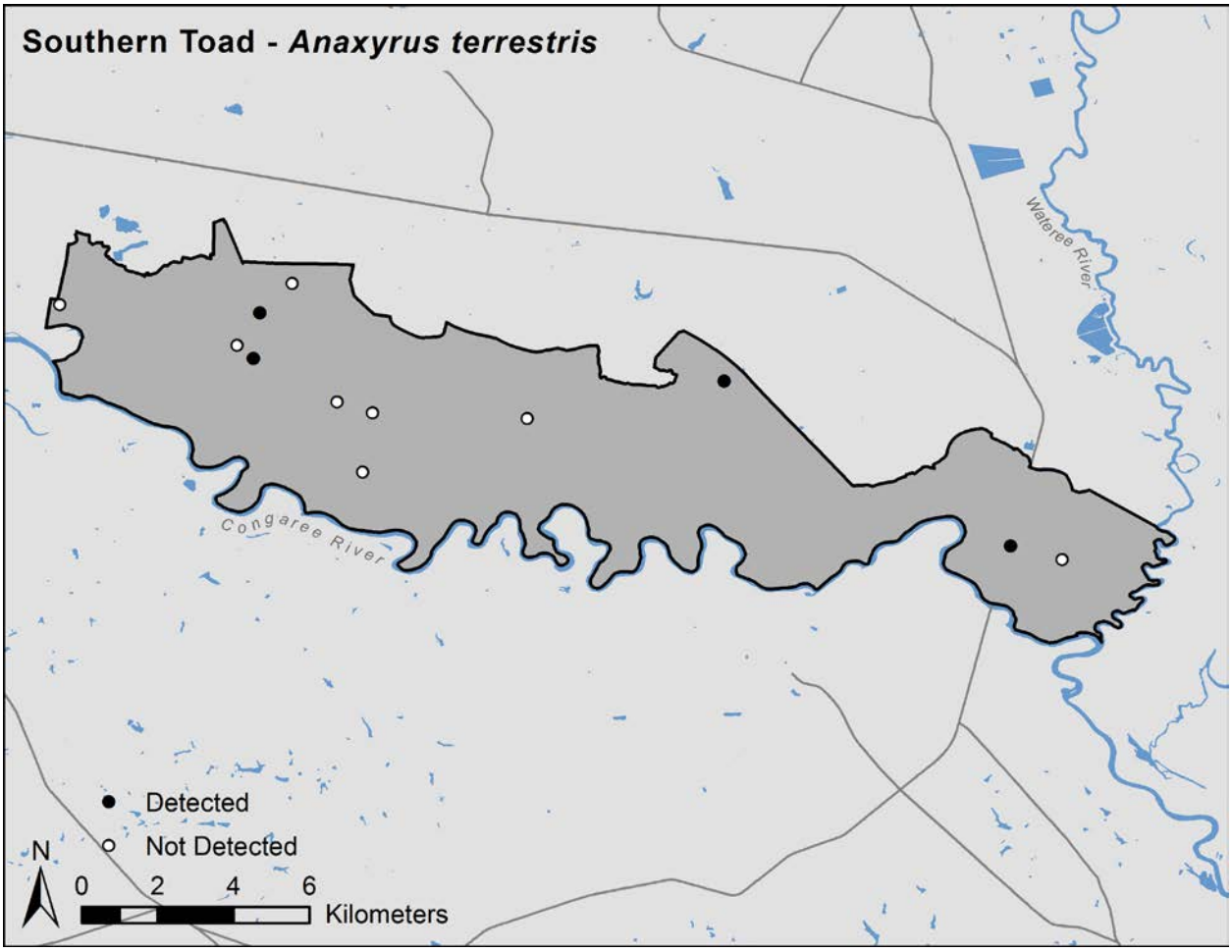

Figure B-1. Sampling locations where Southern Toad (*Anaxyrus terrestris*) was detected at Congaree National Park, 2011.

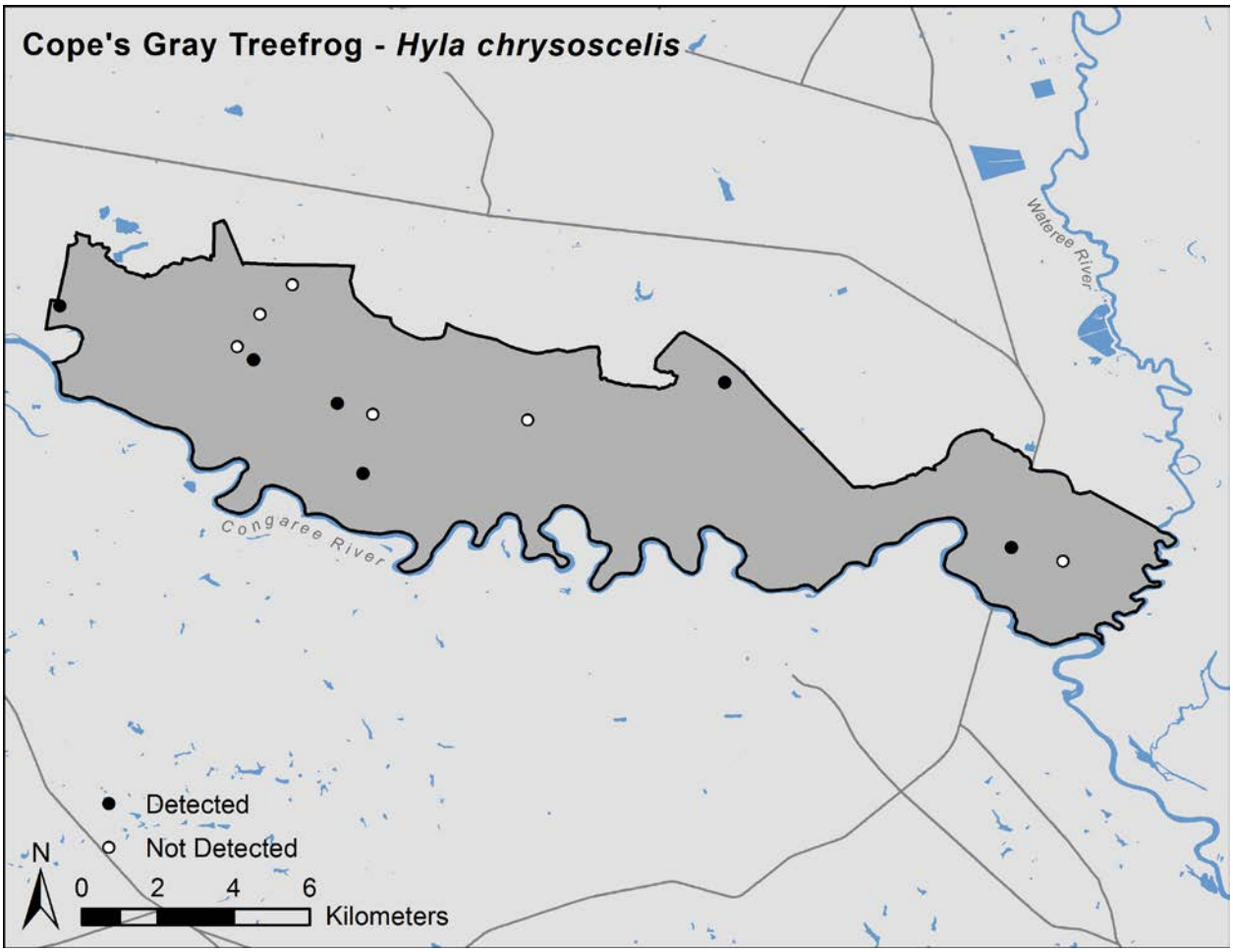

Figure B-2. Sampling locations where Cope's Gray Treefrog (*Hyla chrysoscelis*) was detected at Congaree National Park, 2011.

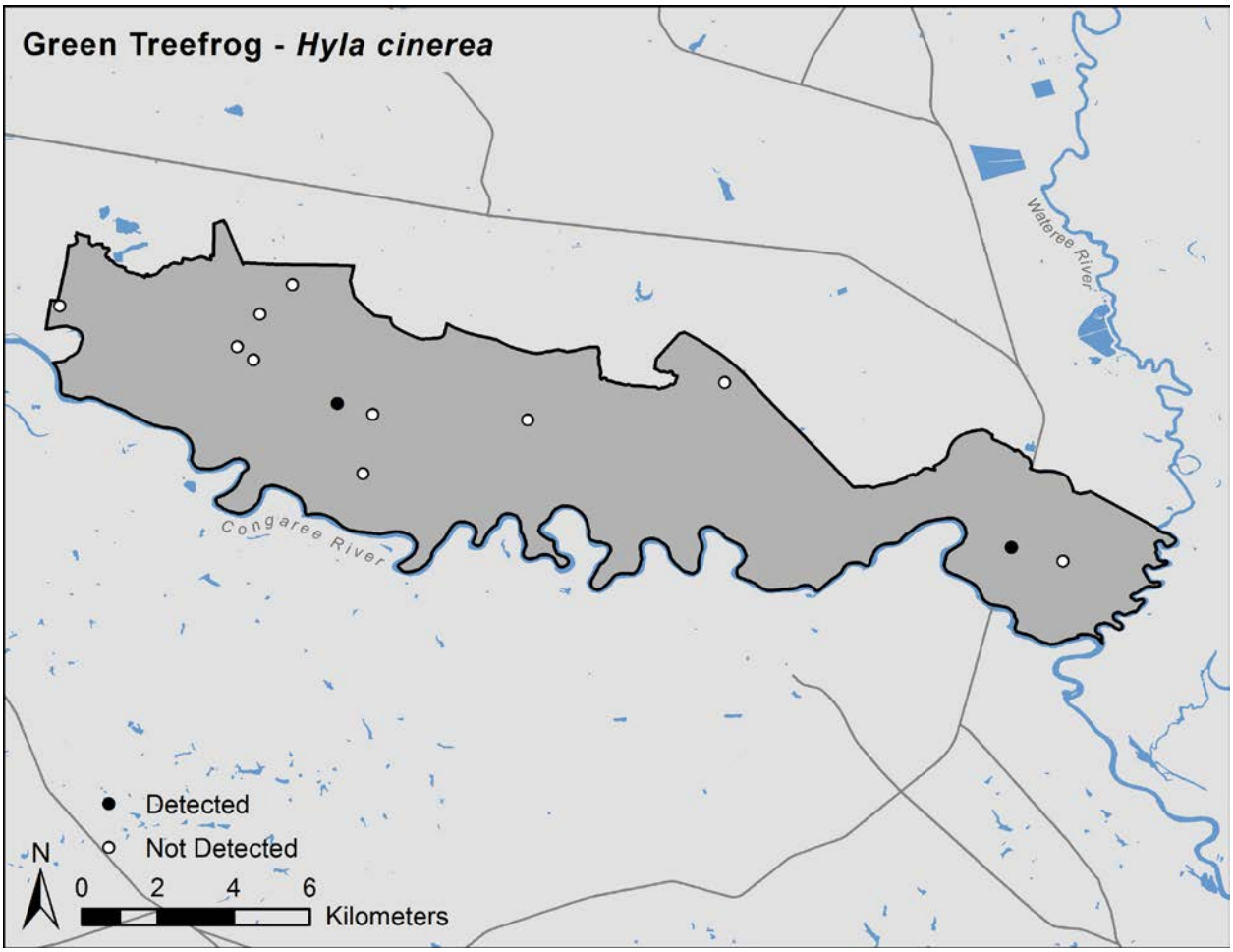

Figure B-3. Sampling locations where Green Treefrog (*Hyla cinerea*) was detected at Congaree National Park, 2011.

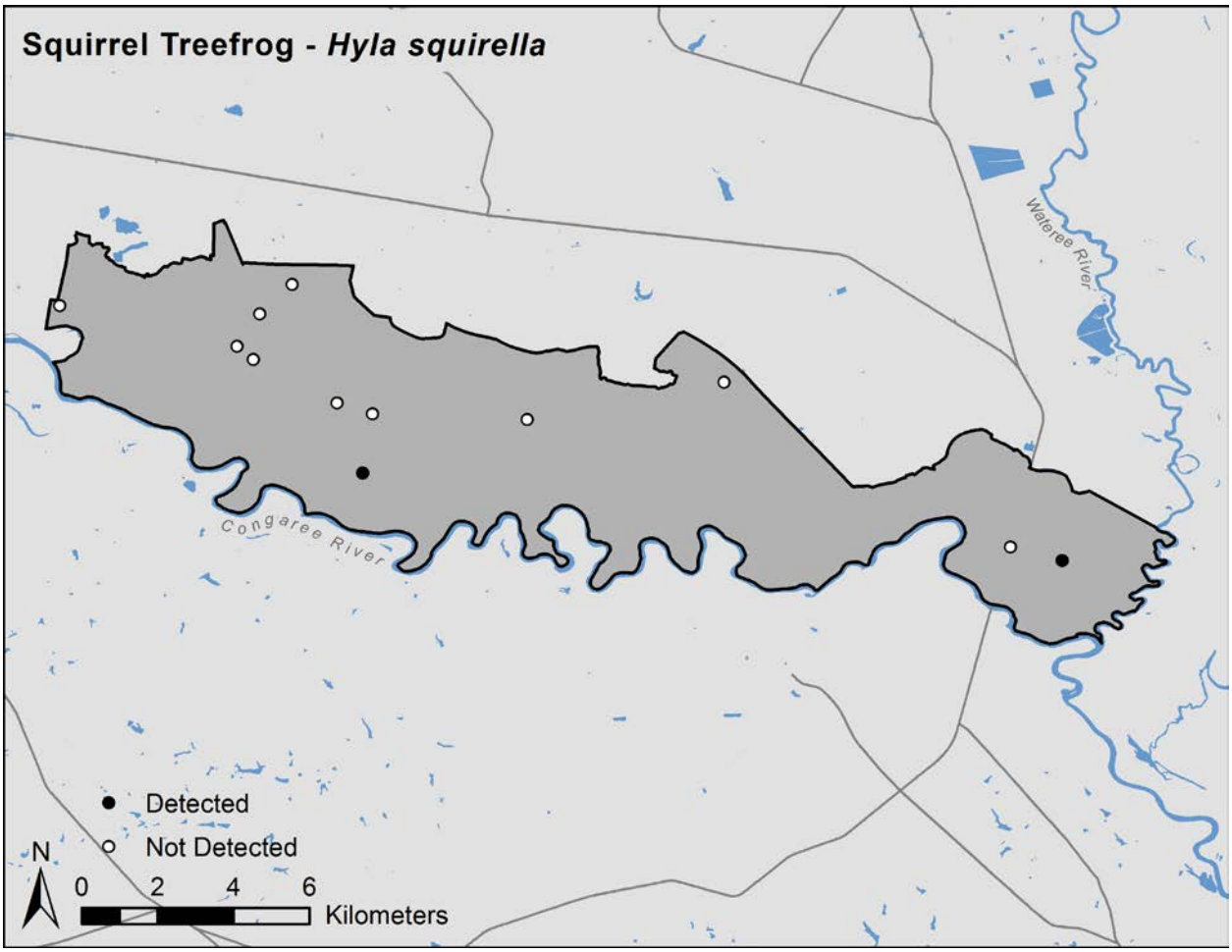

Figure B-4. Sampling locations where Squirrel Treefrog (*Hyla squirella*) was detected at Congaree National Park, 2011.

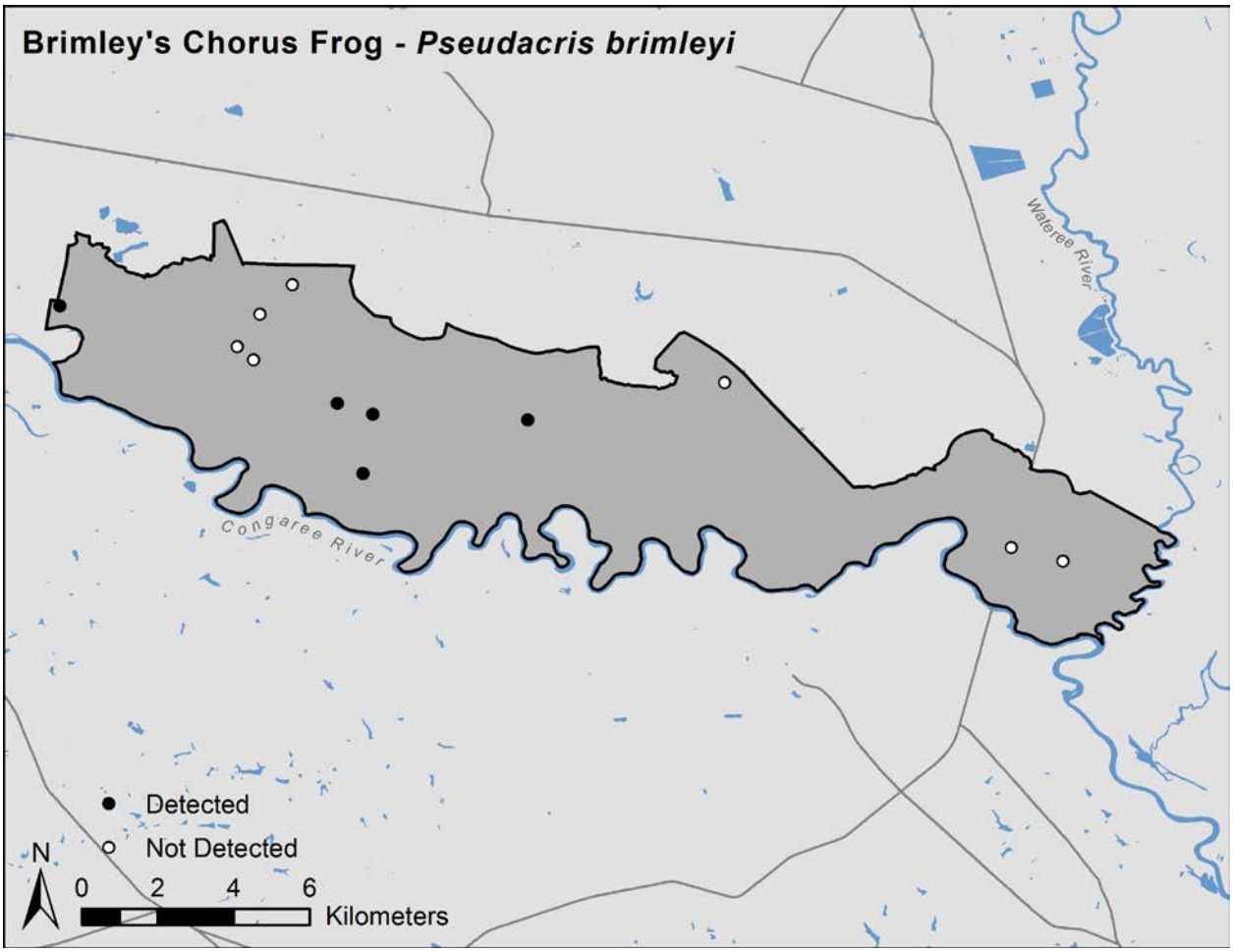

Figure B-5. Sampling locations where Brimley's Chorus Frog (*Pseudacris brimleyi*) was detected at Congaree National Park, 2011.

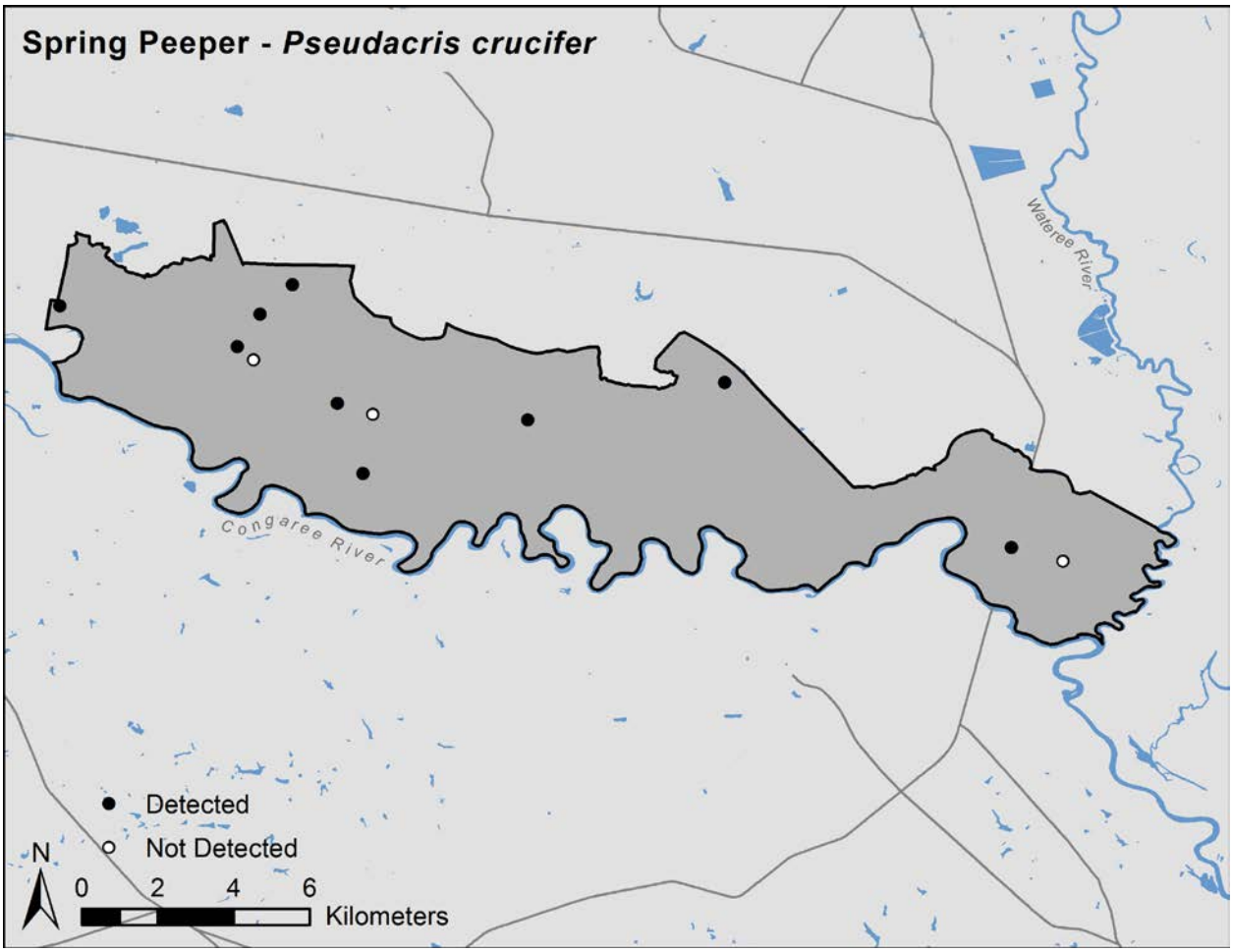

Figure B-6. Sampling locations where Spring Peeper (*Pseudacris crucifer*) was detected at Congaree National Park, 2011.

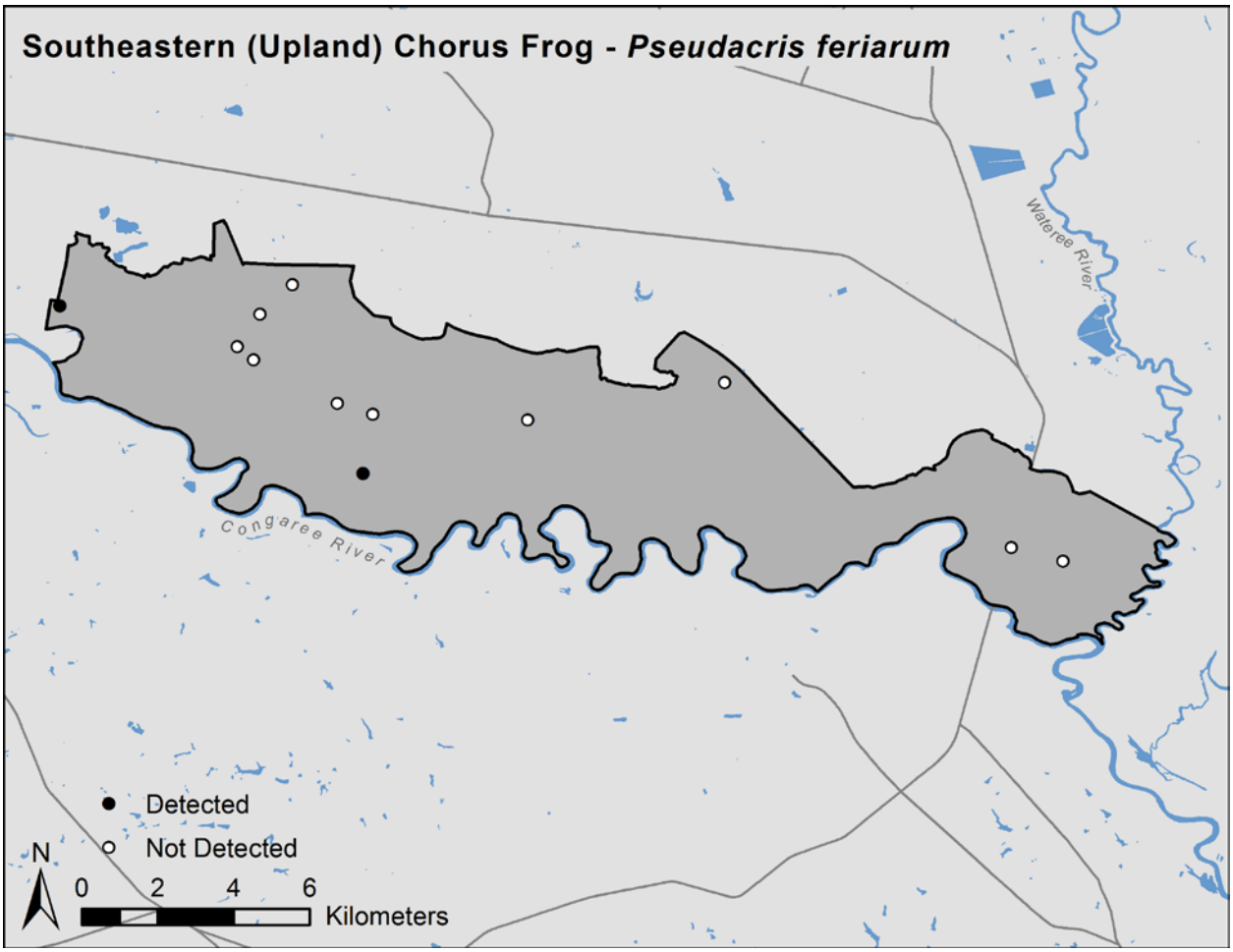

Figure B-7. Sampling locations where Southeastern (Upland) Chorus Frog (*Pseudacris feriarum*) was detected at Congaree National Park, 2011.

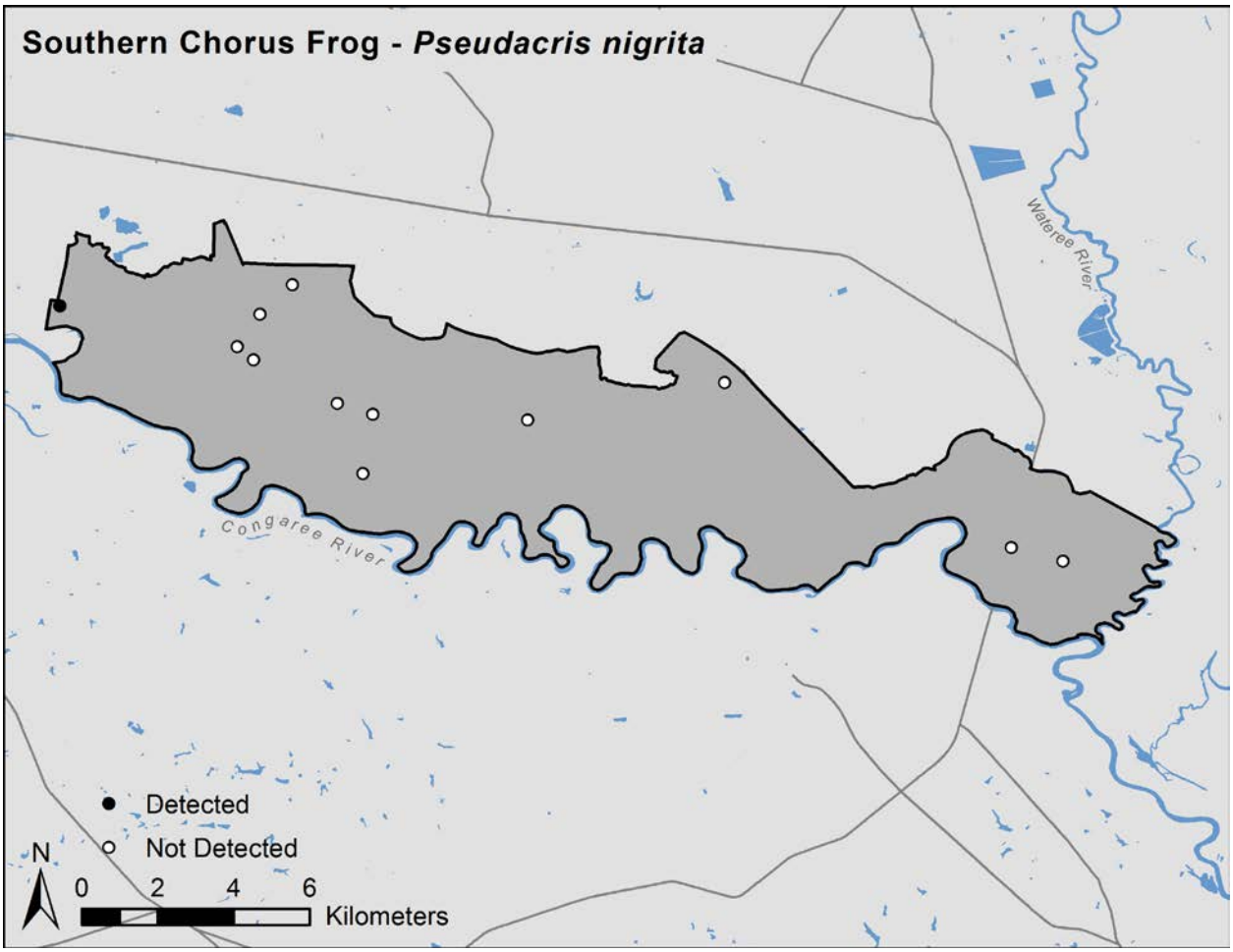

Figure B-8. Sampling location where Southern Chorus Frog (*Pseudacris nigrita*) was detected at Congaree National Park, 2011.

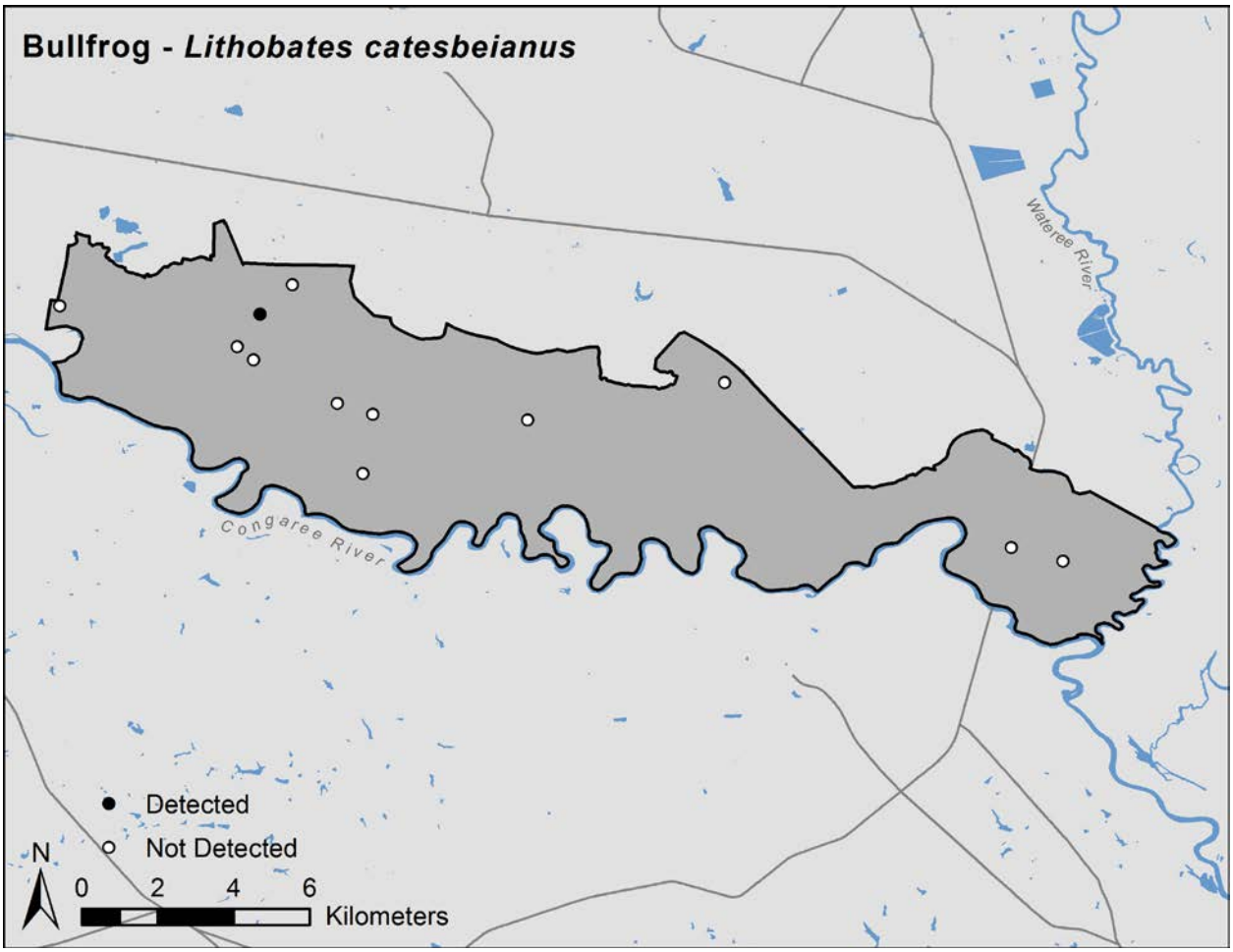

Figure B-9. Sampling location where Bullfrog (*Lithobates catesbeianus*) was detected at Congaree National Park, 2011.

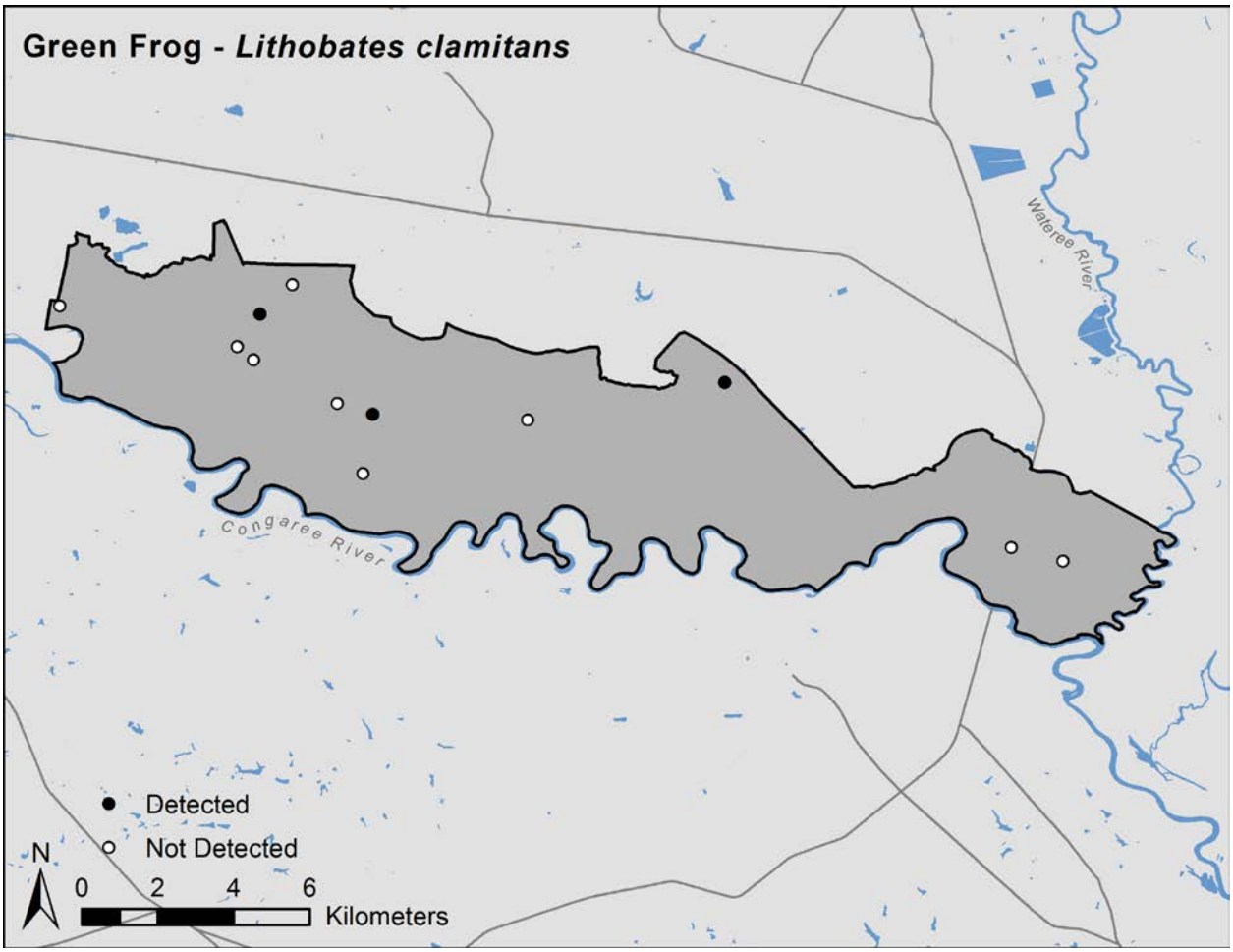

Figure B-10. Sampling locations where Green Frog (*Lithobates clamitans*) was detected at Congaree National Park, 2011.

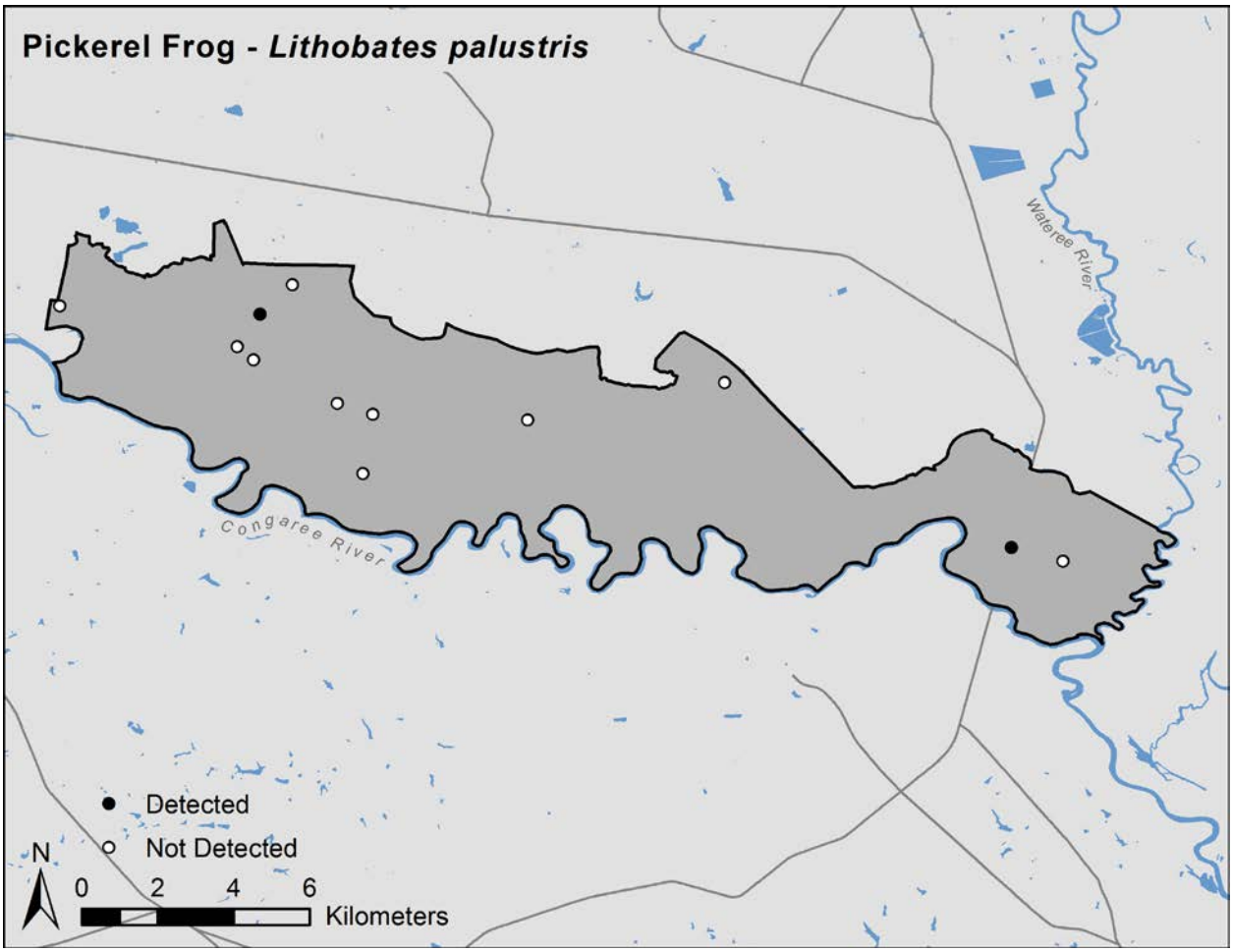

Figure B-11. Sampling locations where Pickerel Frog (*Lithobates palustris*) was detected at Congaree National Park, 2011.

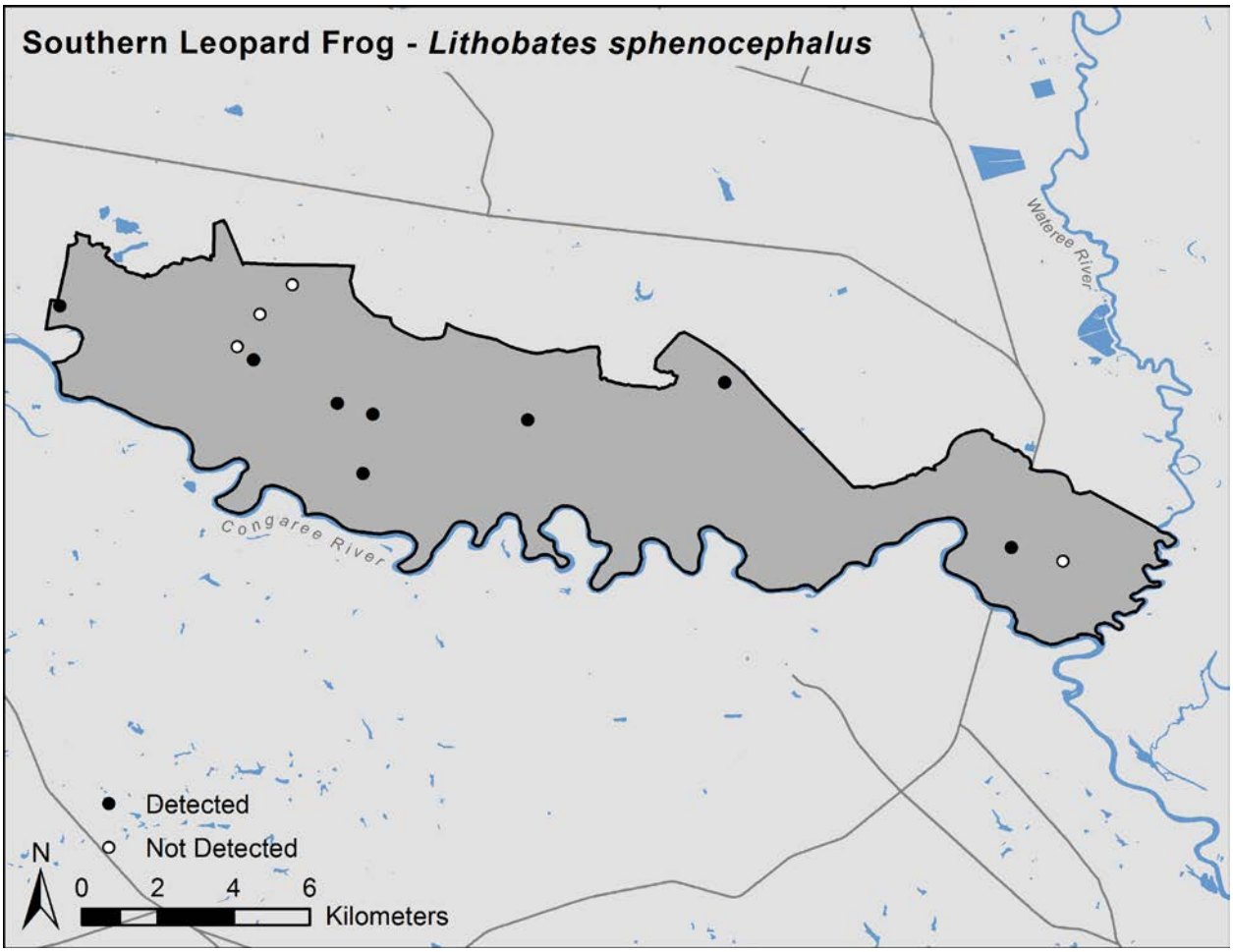

Figure B-12. Sampling locations where Southern Leopard Frog (*Lithobates sphenocephalus*) was detected at Congaree National Park, 2011.