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Natural Resource Stewardship and Science

Amphibian Community Monitoring at Kennesaw Mountain National Battlefield Park, 2011

Natural Resource Data Series NPS/SECN/NRDS—2013/529

ON THE COVER
Cope's Gray Treefrog (*Hyla chrysoscelis*)
Photograph by: Briana Smrekar

Amphibian Community Monitoring at Kennesaw Mountain National Battlefield Park, 2011

Natural Resource Data Series NPS/SECN/NRDS—2013/529

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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 amphibian community vital signs monitoring data collected at Kennesaw Mountain National Battlefield Park in 2011.

- During 2011, visual encounter surveys (VESs) and automated recording devices (ARDs) were used to collect data at 30 spatially balanced random locations within Kennesaw Mountain National Battlefield Park.

- Auditory recordings were collected from 3/14/2011 through 6/8/2011 and visual surveys were conducted from 7/9/2011 through 7/25/2011.

- We detected 18 amphibian species during 2011 monitoring activities. We detected anuran vocalization from eight species using the ARDs. We detected 101 post-metamorphic amphibians in 18 identifiable taxa (species or order) and 77 larval stage amphibians in four taxa during the VESs.

- A total of 117 vocal detections were made using the ARD recordings, where each detection represents an identifiable observation of a species or species group during one night of monitoring at a sampling location.

- We detected 80 reptiles and reptile signs in 15 identifiable taxa during the VESs.

- Spring peeper (*Pseudacris crucifer*) and Cope's gray treefrog (*Hyla chrysoscelis*) had the highest frequency of occurrence at KEMO in 2011.

- Spring peeper had the highest relative frequency of detection of anuran vocalizations during the 77-day ARD recording period.

- The spotted or Northern dusky salamander (*Desmognathus conanti* or *fuscus*) had the highest relative abundance among amphibians during visual surveys.

- Cope's gray treefrog was the most widely distributed amphibian, found throughout the north-south expanse of the park.

- Four sampling locations (SL) in the park were found to have the highest species diversity at eight (SL 8, 17, 18) or nine (SL 2) species present.

- The green treefrog (*Hyla cinerea*) and the spotted dusky salamander (*Desmognathus conanti*) were added to the amphibian species list at Kennesaw Mountain.

- Three reptiles were detected for the first time in the park and were added to the species list; smooth earth snake (*Virginia valeriae*), red-bellied water snake (*Nerodia erythrogaster erythrogaster*), and broad-headed skink (*Eumeces laticeps*).

- No non-native species were found.

- Amphibian communities were sampled again in 2012 and will next be sampled in 2016.

- 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.

This report summarizes data collected as a part of the Southeast Coast Network Vital Signs Monitoring Program's efforts to assess the status and trends of amphibian communities at Kennesaw Mountain National Battlefield Park.

Study Area

Kennesaw Mountain National Battlefield Park (KEMO), a 2,923-acre (1183 ha) park in the metropolitan Atlanta area, includes the 1,808-foot (551 m) peak of Kennesaw Mountain, Little Kennesaw Mountain, and hundreds of acres of mixed hardwood / pine forests intermixed with a number of grassy fields (Figure 1). Forested areas generally consist of oaks (*Quercus* spp.), hickories (*Carya* spp.), and loblolly pine (*Pinus taeda*). Included are more than 22 miles (35.4) of designated hiking trails that attract hundreds of recreational visitors daily. The Park's location in the metropolitan Atlanta area makes it the second-most visited battlefield in the National Park

System, and has earned it a position on the Secretary of Interior's list of 25 most threatened parks.

Largely because of its proximity to Atlanta, major threats to natural resources exist at KEMO. The development of Cobb County and greater metro Atlanta makes the lands within Kennesaw Mountain relatively valuable for localized plant and animal communities. Cobb County has plans to expand roads and highways that traverse the park and pose a potential threat to both cultural and natural resources. Air pollution also poses a major threat to the Park, which is located in a designated ozone nonattainment area. Vegetation in KEMO is considered at high risk of injury from ozone.

Additionally, there are minor threats from encroachment of adjacent landowners, non-native invasive plant species, and industrial air and water pollution. Since 1993, Southern pine beetle (*Dendroctonus frontalis*) infestations have killed thousands of pine trees throughout the park and the resulting increase in fuels laying on the forest floor pose an increased fire risk. The mitigation of encroachments and the removal of non-native plants are ongoing programs.

KEMO has 24 known amphibian species, including two species, Green Treefrog (*Hyla cinerea*) and Spotted Dusky Salamander (*Desmognathus conanti*), which were added to the park's species list as a result of the monitoring results presented herein (Table A-1, NPSpecies 2013). The amphibians consist of 12 species in Anura (frogs and toads) and 12 species in Caudata (e.g. salamanders, newts, amphiumas, sirens).

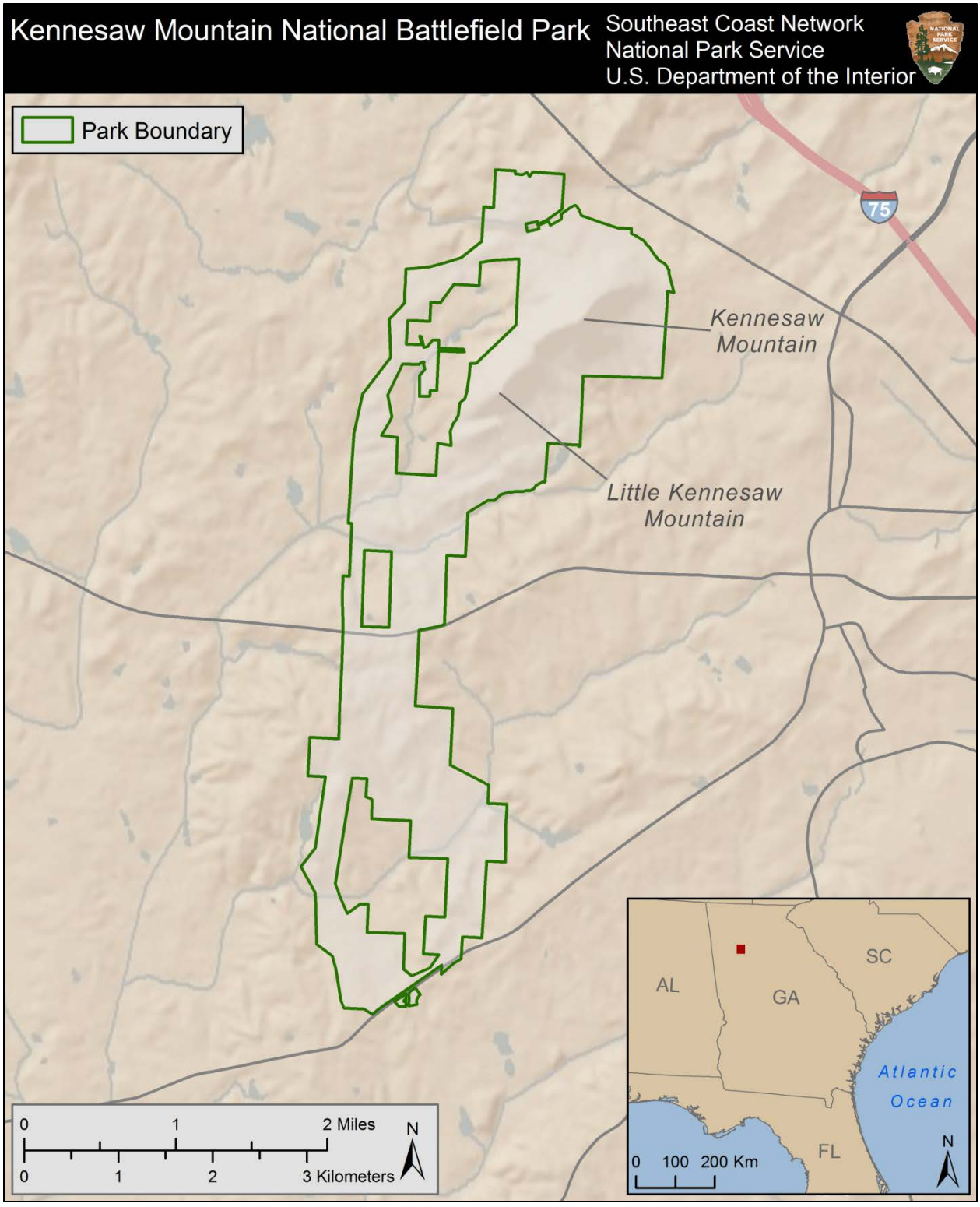


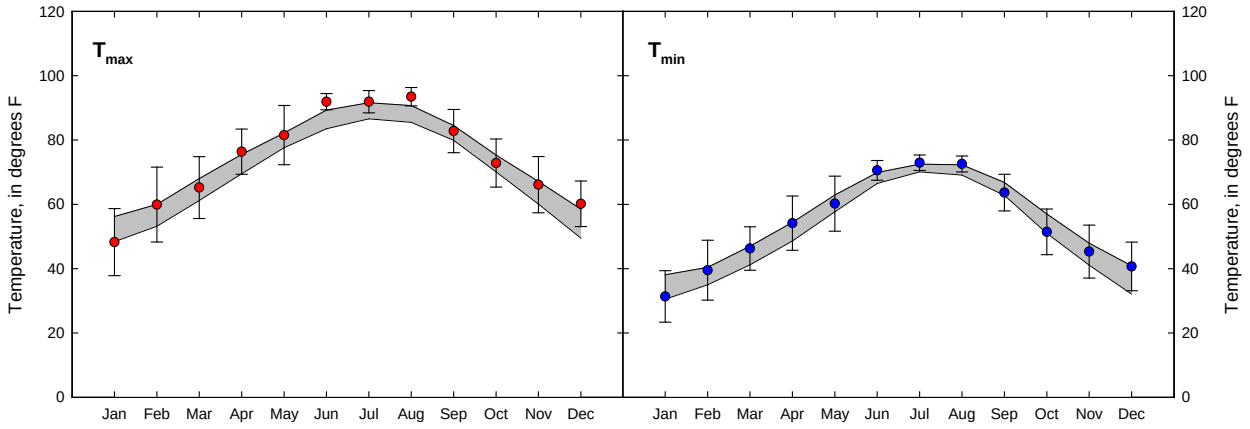
Figure 1. Location of Kennesaw National Battlefield Park

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 Atlanta Hartsfield International Airport and Dallas 7 NE weather stations, mean monthly temperatures were above average during much of the SECN amphibian monitoring time frame of March through July 2011 (Figure 2). High temperatures ranged from 64.9°F to 92.2°F, while lows ranged from 41.4°F to 69.7°F during the sampling period. June recorded the highest departures from average temperature (Wright 2012). Precipitation during the same period was at normal levels during the first part of the SECN sampling period, but below average from May through July. Total annual precipitation averaged 7.45 inches below normal for the greater northern Atlanta area (Figure 3).

A.



B.

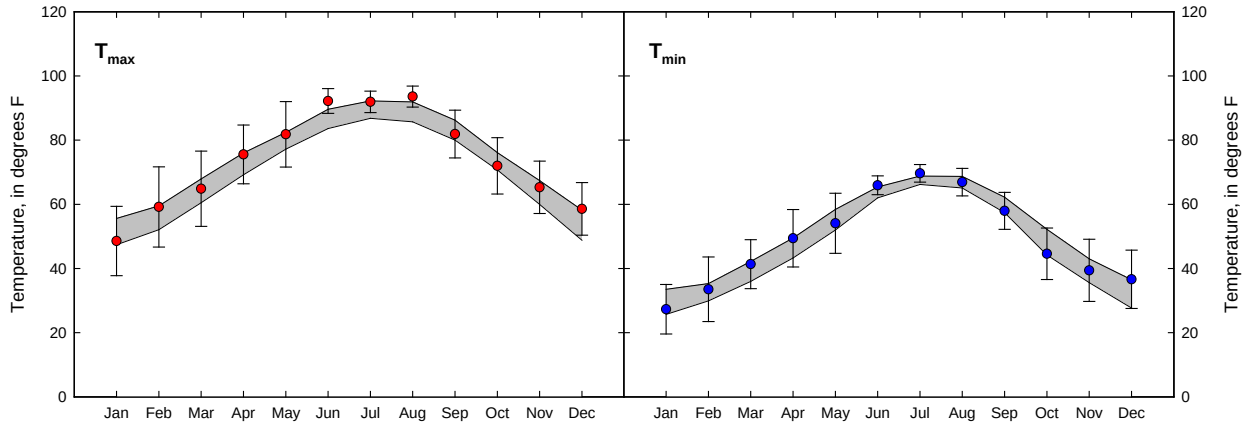
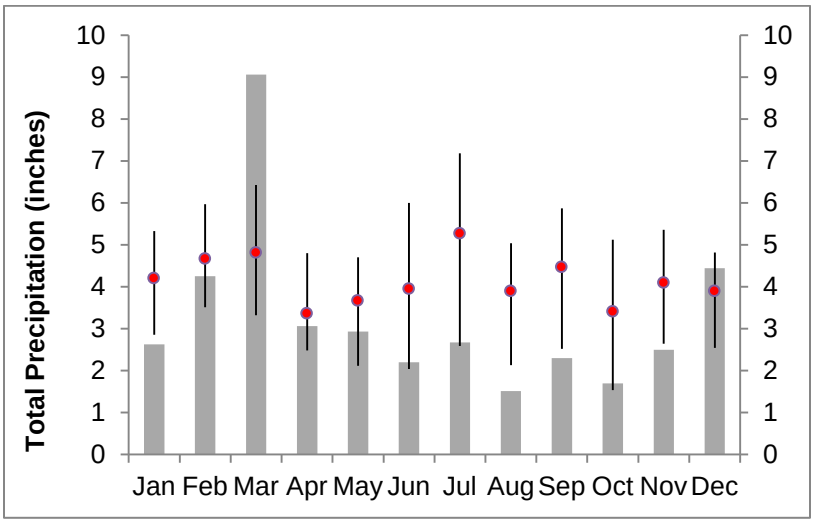


Figure 2. 2011 average monthly temperature and the 30-year (1981 – 2010) average for A. Atlanta Hartsfield International Airport and B. Dallas 7 NE stations. Units = °F. Points indicate the 2011 average monthly maximum and minimum temperatures. Error bars indicate +/- standard deviation. The dual solid lines bound the standard deviation around the 30-year (1981-2010) mean monthly temperature.

A.



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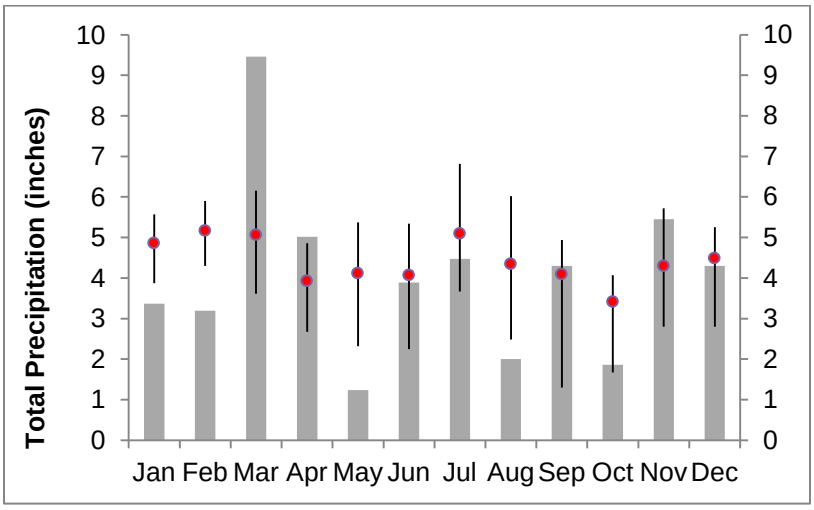

Figure 3. Total monthly precipitation during 2011 and the 30-year (1981 - 2010) monthly averages for A. Atlanta Hartsfield International Airport and B. Dallas 7 NE stations. The gray columns represent 2011 total monthly precipitation. The red circles represent the 30-year average; the lines indicate the 25th and 75th percentile of the 30-year normal data for each month.

At the time when Visual Encounter Surveys were conducted (7/9/2011 to 7/25/2011), conditions were extremely dry with negligible precipitation observed and soil moisture averaging approximately 0.7% (Table 1).

Table 1. Environmental Variables at KEMO, 2011.

Parameter	Average	Standard Deviation	Notes
Noise	1	N/A	Slightly affecting sampling, barely reduces hearing
Precipitation	0.00	N/A	No Precipitation
Relative Humidity (%)	88.58	8.6	
Soil Moisture (%)	0.70	0.31	
Temperature (ºF)	76.61	6.2	
Wind Speed	0.00	N/A	<1 mph

[1] Noise codes are determined in the field as follows: 0 – No appreciable effect, no background noise; 1 – Slightly affecting sampling, barely reduces hearing; 2 – Moderately affecting sampling, noticeable reduction of hearing; 3 – Seriously affecting sampling, noticeable reduction of hearing; 4 – Profoundly affecting sampling, greatly reduced hearing.

[2] Precipitation codes are determined in the field as follows: 0 – None; 1 – Mist or fog; 2 – Light drizzle; 3 – Light rain; 4 – Heavy rain; 5 – Sleet; 6 – Snow.

[3] Wind speed codes are determined in the field as follows: 0 – Calm (< 1mph), smoke rises vertically; 1 – Light air (1-3 mph), smoke drifts, weather vane inactive; 2 – Light breeze (4-7 mph), leaves rustle, can feel wind on face; 3 – Gentle breeze (8-12 mph), leaves and twigs move around, small flags extend; 4 – Moderate breeze (13-18 mph), moves thin branches, raises loose papers; 5 – Fresh breeze (19-24 mph), small trees begin to sway; 6 – Strong breeze (>24 mph), large branches moving, wind whistling.

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 amphibian 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 amphibian 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 amphibian 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.

Additional amphibian and reptile data based on visual encounter methods that were being tested as a part of protocol development in FY 2011 are also presented below.

Methods

Sampling Design

To allow for park-wide inference, the KEMO 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). Alternate points were used when selection criteria (i.e., including safety and access issues) were not met. In 2011, Amphibian Communities were sampled at 30 locations that met the selection criteria (i.e., safety and access considerations) as described in Byrne et al. (2013 *in review*) (Figure 4).

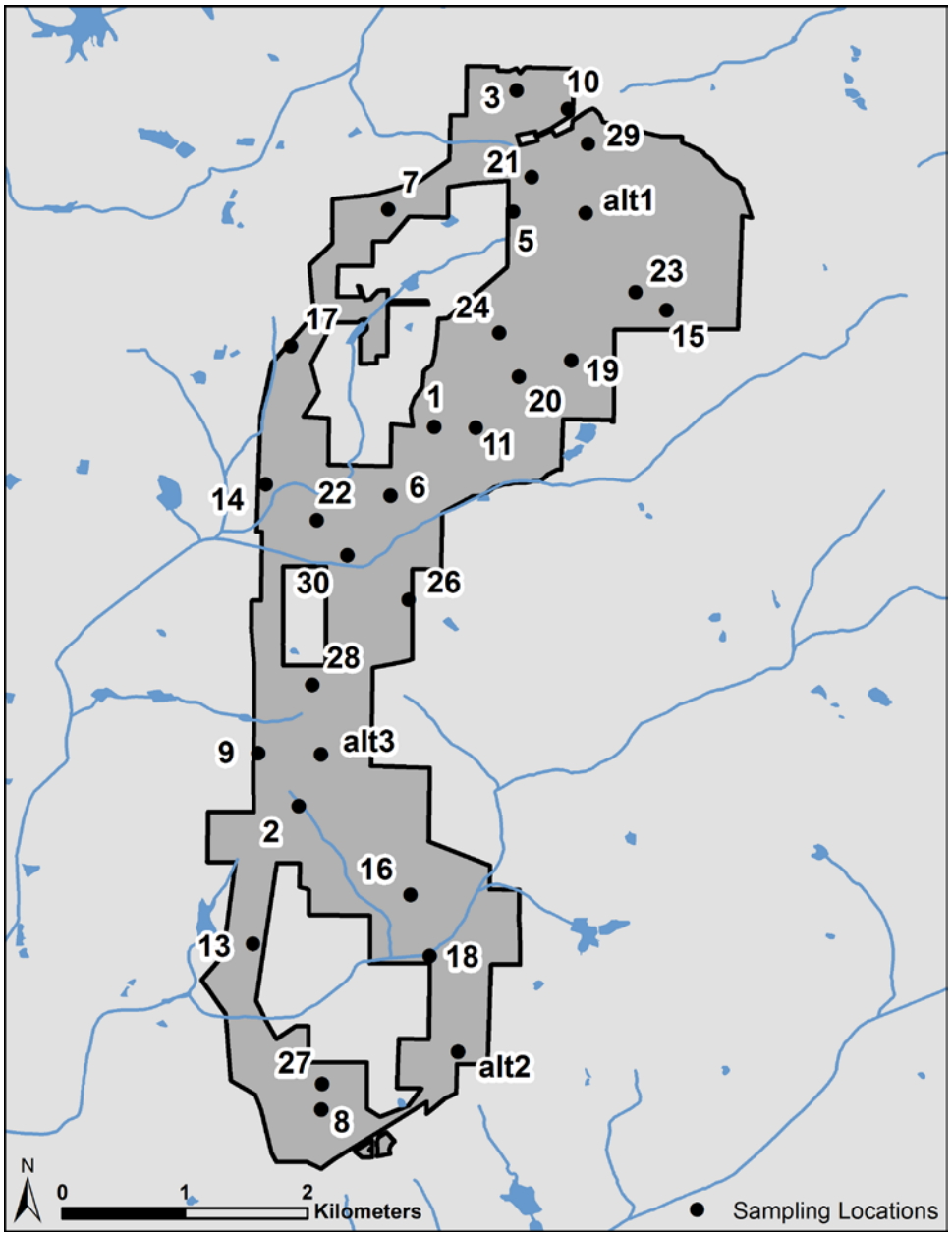

Figure 4. Spatially-balanced random sampling locations Kennesaw Mountain National Battlefield Park, 2011.

Sampling Methodology

Three sampling techniques were used as part of SECN amphibian monitoring, including a combination of active and passive sampling techniques. The active techniques were a time- and area-constrained medium-intensity visual encounter survey (VES) that was conducted systematically through the 0.5-ha macroplot, and the dip-net techniques incorporated in sampling locations with aquatic communities. All species or species sign detected by sight or sound were recorded as part of the VESs. The passive technique was an automated-recording device (ARD) programmed to record every four days from 20:00 (8:00 pm) to 06:50 am for 30 seconds of every 10 minutes. Use of multiple techniques, as a "toolbox" approach (Olson et al. 1997), is generally agreed to be the most effective means to monitor amphibian communities (Hutchens and DePerno 2009). The sampling techniques were co-located, with the ARDs deployed at the center point of each 0.5-ha macroplot where VES sampling occurred (Figure 5). All three techniques adequately detect any species that occurs in the 0.5-ha macroplot.

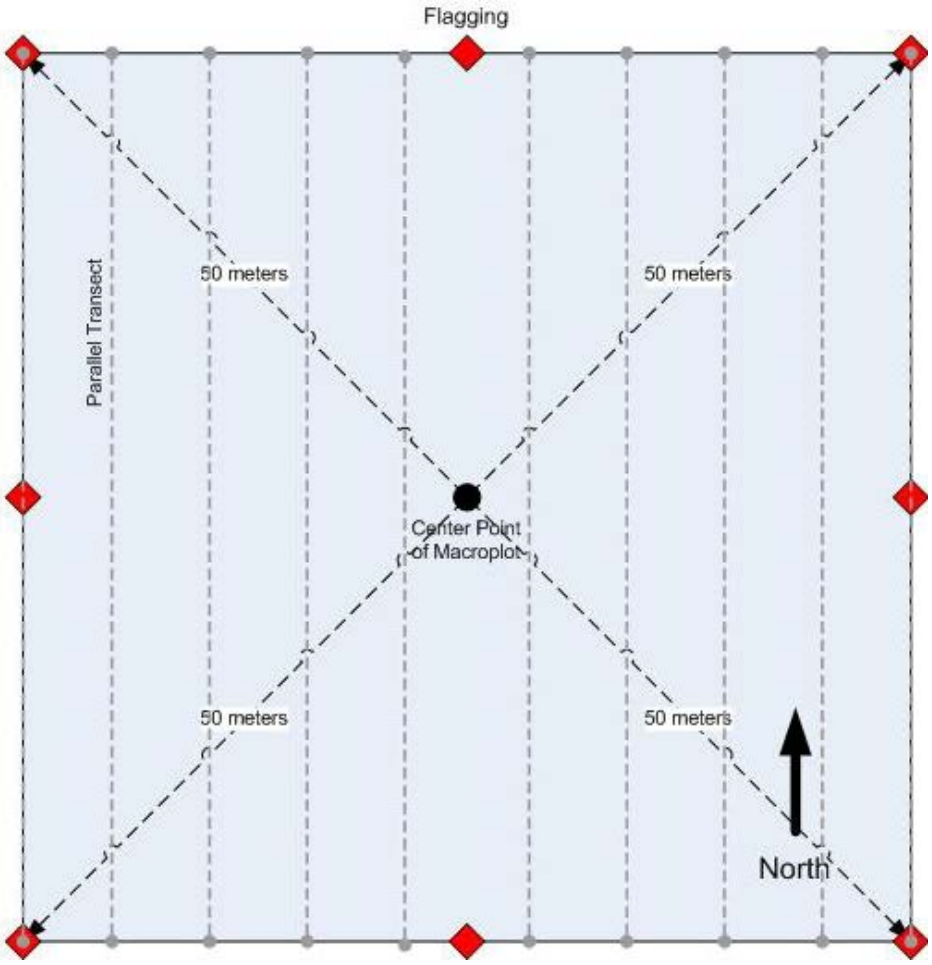

Figure 5. Macroplot (0.5-ha) layout for amphibian community monitoring in Southeast Coast Network parks. Visual encounter surveys (VESs) occur along parallel transects within the macroplot; Automated recording devices (ARDs) are deployed for 77 days at or near the center point of the macroplot.

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 77 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 from 3/14/2011 through 6/8/2011. A total of 15,676 minutes were recorded by all of the devices deployed at Kennesaw Mountain National Battlefield Park. The ARD malfunctioned or was damaged in a storm and recorded only partial data at five sampling locations (03, 05, 06, 15, and Alt 02). The device malfunctioned and did not record any data at three locations (11, 16, and 19).

Visual Encounter Surveys

The VES consisted of a medium-intensity time-constrained survey, the duration of which is determined at the sampling location based on vegetation density prior to initiation of the survey. All potential cover objects (e.g., leaf litter, under logs/rocks, other potential cover items) within the plot were searched and all species detected were identified and recorded (including reptiles). Cover objects were returned to their original position to reduce habitat impacts from monitoring activities. Animals were captured only to facilitate accurate identification. If streams or wetlands were encountered within the macroplot, dip-nets and hand-capture techniques were used to detect and identify aquatic amphibians or larvae.

Visual Encounter Surveys were conducted at Kennesaw Mountain National Battlefield Park from 7/9/2011 to 7/25/2011.

Taxonomic Standards

Despite a well-trained field crew, complete identification of all individuals encountered was not always possible due to the quick and evasive nature of many species. Species are, however identified to most refined taxonomic level possible. For example, while the surveyors are approaching a small pool surrounded by dense vegetation they catch brief glimpses of and hear several frogs dive into the pool prior to completing a full visual inspection of the individuals necessary for identification. While the majority of these species could most likely be identified to the genus or family level (i.e., Unknown *Lithobates* or Ranidae in this instance) based upon knowledge of the site and the local fauna, a conservative estimation is used and these species are identified to Order as "Unknown Anuran".

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 are conducted accordingly.

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 abundance is the number of individuals of a particular species expressed as a percentage of the total number of amphibians in the sample. The sample size is the total number of amphibians counted at all sampling locations in the park. 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.

Results

Community Composition

While the primary purpose of this SECN monitoring effort was to detect amphibians, due to their common habitat use reptiles were also encountered during VESs. It is important to note that VESs and ARDs are not considered effective tools to survey for many reptile species, nor was the intent of VES implementation to target reptiles. Although not the target of the SECN's amphibian sampling protocol, we have included a reptile species detection data summary in Appendix C.

Note that due to interbreeding, and/or a similar appearance or vocalization, it was not always possible to differentiate between several groups of amphibians. In these cases, the two similar species were grouped together for data analysis, and it is likely that they serve the same ecological niche. For this report, the spotted and Northern dusky salamanders (*Desmognathus conanti* and *fuscus*) have been grouped, Northern and Southern cricket frogs (*Acris crepitans* or *gryllus*) have been grouped under *Acris* sp., and southern two-lined (*Eurycea cirrigera*) and three-lined salamander (*Eurycea guttolineata*) larvae have been combined under *Eurycea* sp.

We detected 18 amphibian species during sampling activities at KEMO in 2011. During the VESs, we detected 101 post-metamorphic amphibians in 15 species and 4 genera and 77 larval stage amphibians in four taxa (genus or species) (Table A-3). Using ARDs we detected vocalizing anurans in eight species (Table 2). Six amphibian species composed approximately 75% of the amphibian post-metamorphic VES sample and three species accounted for 85% of the vocalization detections.

Cope's gray treefrog (*Hyla chrysoscelis*), detected at approximately 27% of the sampling locations, had the highest frequency of occurrence (naïve occupancy) of all amphibians detected during our 2011 surveying efforts (Table 2). The spring peeper (*Pseudacris crucifer*), detected at 23% of sampling locations, had the second highest frequency of occurrence, followed by the Southeastern (upland) chorus frog (*Pseudacris feriarum*) and Fowler's toad (*Anaxyrus fowleri*), each with a frequency of occurrence of 20% across sampling locations at KEMO. Among Caudates, the slimy salamander (*Plethodon glutinosis*) and the spotted or Northern dusky salamander (*Desmognathus conanti* or *fuscus)* had the highest frequency of occurrence; each was detected at 10% of the sampling locations. The cricket frog (*Acris* sp.), green treefrog (*Hyla cinerea*), and bullfrog (*Lithobates catesbeianus*) had the lowest frequency of occurrence among anurans at HOBE in 2011, while the marbled (*Ambystoma opacum*), seal (*Desmognathus monticola*), three-lined (*Eurycea guttolineata*), and red (*Pseudotriton ruber*) salamanders had the lowest naïve occupancy among Caudates.

The spring peeper had the highest relative detection frequency of vocalizations recorded by ARDs over the 77-day sampling period, followed by the Cope's gray treefrog and the Southeastern (upland) chorus frog. Spring peeper vocalizations composed nearly 40% of all vocalizations detected, while the Cope's gray treefrog and Southeastern chorus frog each accounted for 23% of all vocalizations detected (Figure 6). The green frog (*Lithobates clamitans*) and the bullfrog had the lowest relative detection frequency of vocalizations during the recording period.

The spotted or Northern dusky salamander had both the highest relative abundance of all post-metamorphic amphibians detected during the VESs, and the highest relative abundance among Caudates, accounting for approximately 26% of all post-metamorphic amphibians and nearly 57% of all salamanders counted during 2011 surveying activities (Figure 7). The spotted or Northern dusky salamander, along with the slimy salamander, accounted for 41% of all post-metamorphic amphibians detected. The Fowler's toad had the highest relative abundance among post-metamorphic anurans, accounting for 12% of the total number of adult amphibians detected during the VESs. Approximately 43% of all detections during the VESs were of amphibians in a larval stage (Table A-3). Among larval stage amphibians, the Southern two-lined or three-lined salamander (*Eurycea cirrigera* or *guttolineata*) and the spotted or Northern dusky salamander had the highest relative abundances, together accounting for approximately 78% of all larval amphibian detections. No non-native species were detected.

Table 2. Percentage of sampling locations where each amphibian species was detected (i.e., naïve occupancy) by method and across methods at Kennesaw Mountain National Battlefield Park, 2011. NA indicates that the method does not apply to this species.

	Detection Method		
Species	**All**	**VES**	**ARD**
Anura			
Cope's Gray Treefrog	26.7	6.7	22.2
Spring Peeper	23.3	13.3	18.5
Southeastern (Upland) Chorus Frog	20.0	6.7	18.5
Fowler's Toad	20.0	16.7	3.7
Green Frog	13.3	10.0	3.7
Ranidae sp.	13.3	13.3	NA
American Toad	10.0	10.0	0.0
Southern Leopard Frog	10.0	10.0	0.0
Pickerel Frog	6.7	6.7	0.0
Cricket Frog	3.3	0.0	3.7
Green Treefrog	3.3	0.0	3.7
Bullfrog	3.3	0.0	3.7
Anaxyrus sp.	3.3	3.3	NA
Pseudacris sp.	3.3	3.3	NA
Caudata			
Slimy Salamander	10.0	*10.0*	*NA*
Spotted/Northern Dusky Salamander	10.0	*10.0*	*NA*
Southern Two-lined Salamander	6.7	*6.7*	*NA*
Marbled Salamander	3.3	*3.3*	*NA*
Red Salamander	3.3	*3.3*	*NA*
Seal Salamander	3.3	*3.3*	*NA*
Two-lined or Three-lined Salamander	3.3	*3.3*	*NA*
Three-lined Salamander	3.3	*3.3*	*NA*
Total Locations Surveyed	**30**	**30**	**27**

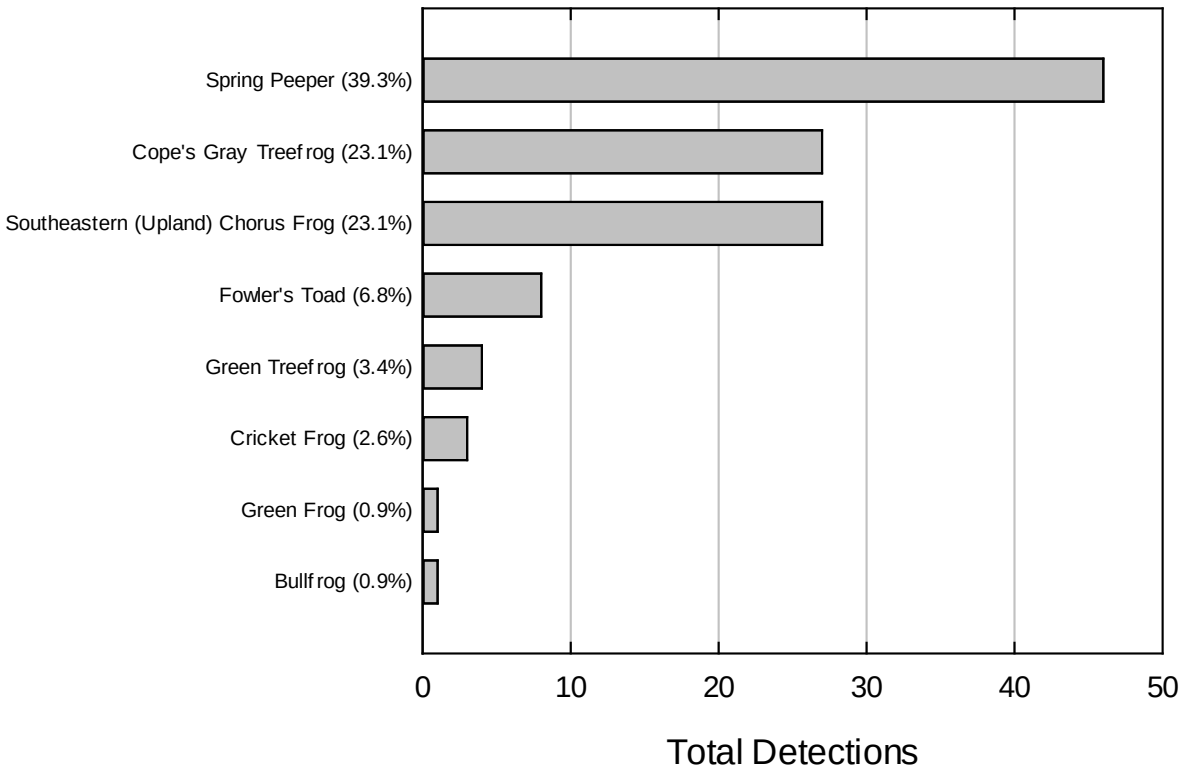

Figure 6. Number of anuran vocalization detections and the percent relative detection frequency (i.e., number of species vocalizations compared to all species' vocalizations) of recorded calls during Automated Recording Device (ARD) deployment (14 March to 8 June 2011) at Kennesaw Mountain National Battlefield Park. Based on n=117 detections.

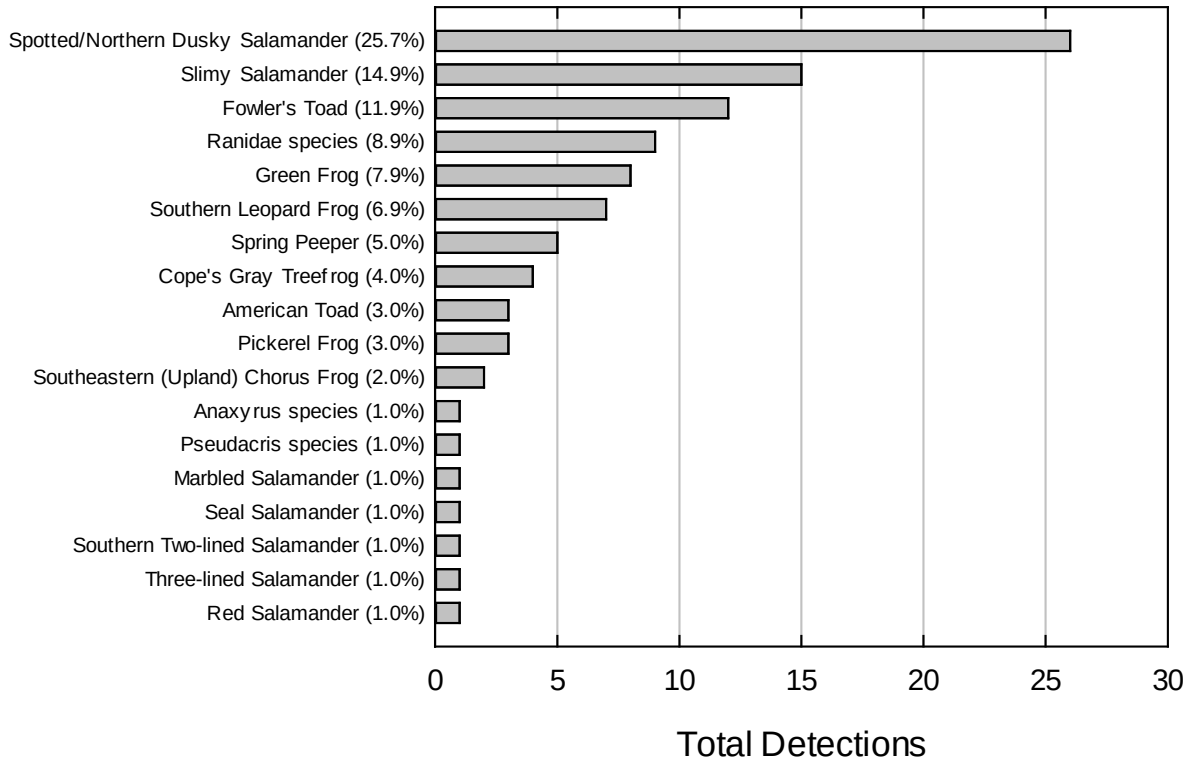

Figure 7. Number of individual amphibians detected and the relative abundance (as a percentage) of each species in the sample of post-metamorphic amphibians detected during visual encounter surveys at Kennesaw Mountain National Battlefield Park, 2011. Based on n=101 detections.

New Species Records

Two amphibian species not previously known to occur at Kennesaw Mountain National Battlefield Park were detected during the 2011 monitoring event, the green treefrog and the spotted dusky salamander (*Desmognathus conanti*) (Table 3.) The green treefrog was detected using the ARDs, and the spotted dusky salamander was detected during the VESs. While the spotted dusky salamander (*Desmognathus conanti*) typically has a more southern range than the Northern dusky salamander (*Desmognathus fuscus*), their ranges overlap in northern Georgia and the two species may interbreed (Mitchell and Gibbons, 2010). Therefore we have combined the two species for data analysis purposes.

Table 3. New amphibian species detected at Kennesaw Mountain National Battlefield Park and recommended NPSpecies classifications.

Scientific Name	Common Name	Abundance	Residency	Nativity	Pest	Management Priority	Exploitation Concerns
Desmognathus conanti	Spotted Dusky Salamander	Unknown	Resident	Native	No	No	No
Hyla cinerea	Green Treefrog	Unknown	Resident	Native	No	No	No

Amphibian Distribution

Cope's gray treefrog was the most widely distributed species at KEMO during the 2011 sampling efforts, detected at locations throughout the north-south expanse of the park (Table 2, Appendix B). The Southeastern chorus frog was also found from the northern to the southern sections of the park, although at fewer locations than the Cope's gray treefrog. Despite being among the top four most frequently occurring species at KEMO in 2011, the spring peeper and Fowler's toad had a more limited distribution in the park. Fowler's toad was detected mostly in the northern extent of the park, while the spring peeper was concentrated at sampling locations in the central and southern sections of the park. The cricket frog, green treefrog, bullfrog, marbled, three-lined, seal, and red salamanders had the narrowest distribution in KEMO, each detected at one location each. Distribution maps for all amphibians that were detected during the monitoring event are presented in Appendix C.

Vocalization Phenology

Of the anurans detected using ARDs at Kennesaw Mountain in 2011, three species would be appropriate candidates to determine trends in vocalization start dates; green treefrog, Cope's gray treefrog, and Fowler's toad. 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 3/27/2011, while the Fowler's toad initiated vocalization on 4/4/2011. The green treefrog was first detected on 5/10/2011 and the bullfrog had a first vocalization date of 5/8/2011 (Figure 8). Two other species, the bullfrog and green frog, were only detected calling at the end of the surveying period, first call date of 5/31/2011. One species was considered an appropriate candidate for tracking end dates due to the timing of its typical vocalization window in the Southeast, which usually closes well before our recording schedule concludes (Dorcas and Gibbons, 2008). Typically, the Spring Peeper (*Pseudacris crucifer*) is used to track calling end dates in the SECN. However, during 2011, the Spring Peeper exhibited an atypical (although not outside the general calling window) pattern and was detected calling at KEMO until the last recording session on 6/7/2011 (Figure 8).

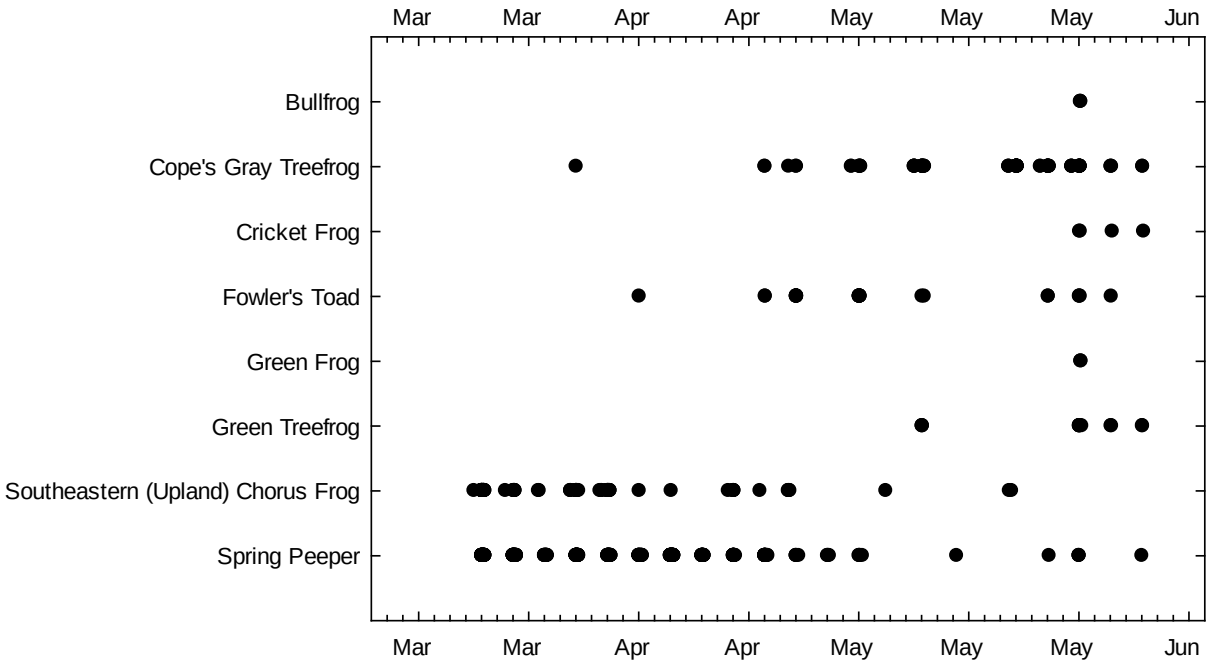

Figure 8. Vocalization phenology for species detected using automated recording devices (ARDs) at Kennesaw Mountain National Battlefield Park, from March 14 to June 8, 2011. Based on n=117 detections.

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Appendix A. Amphibian Species Detection Data

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

Scientific Name	Common Name	NPSpecies	ARD	VES
Anaxyrus americanus	American Toad	X		X
Anaxyrus fowleri	Fowler's Toad	X	X	X
Acris crepitans/gryllus	Cricket Frog	X	X	
Hyla chrysoscelis	Cope's Gray Treefrog	X	X	X
Hyla cinerea	Green Treefrog		X	
Hyla versicolor	Gray Treefrog	X		
Pseudacris crucifer	Spring Peeper	X	X	X
Pseudacris feriarum	Southeastern Chorus Frog	X	X	X
Lithobates catesbeianus	Bullfrog	X	X	
Lithobates clamitans	Green Frog	X	X	X
Lithobates palustris	Pickerel Frog	X		X
Lithobates sphenocephalus	Southern Leopard Frog	X		X
Ambystoma maculatum	Spotted Salamander	X		
Ambystoma opacum	Marbled Salamander	X		X
Desmognathus conanti	Spotted Dusky Salamander			X
Desmognathus fuscus	Northern Dusky Salamander	X		X
Desmognathus monticola	Seal Salamander	X		X
Eurycea cirrigera	Southern Two-lined Salamander	X		X
Eurycea guttolineata	Three-lined Salamander	X		X
Gyrinophilus porphyriticus	Spring Salamander	X		
Plethodon glutinosus	Slimy Salamander	X		X
Plethodon serratus	Southern Red-backed Salamander	X		
Plethodon websteri	Southern Zig-zag Salamander	X		
Pseudotriton ruber	Red Salamander	X		X

Table A-2. Amphibian species or species sign detected at each sampling location at Kennesaw Mountain National Battlefield Park, 2011.

	Sampling Location																												
Species	**1**	**2**	**3**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**26**	**27**	**28**	**29**	**30**	**Alt1**	**Alt2**	**Alt3**
American Toad										X							X					X							
Fowler's Toad											X				X		X	X			X	X							
Anaxyrus sp.																											X			
Cricket Frog															X															
Cope's Gray Treefrog		X				X		X	X			X			X	X								X					
Green Treefrog															X															
Spring Peeper											X	X			X	X				X				X			X			
Southeastern (Upland) Chorus Frog									X			X			X	X				X							X			
Pseudacris sp.				X																										
Bullfrog															X															
Green Frog		X					X								X	X														
Pickerel Frog		X					X																							
Southern Leopard Frog							X									X				X										
Ranidae sp.		X					X									X				X										
Marbled Salamander					X																									
Spotted/Northern Dusky Salamander		X					X									X														
Seal Salamander							X																							
Southern Two-lined Salamander		X					X																							
Three-lined Salamander		X																												
Two-lined or Three-lined Salamander Larvae		X																												
Slimy Salamander		X										X				X														
Red Salamander							X																							

Table A-3. Total number of larval and post-metamorphic detections of amphibian species during visual encounter surveys at Kennesaw Mountain National Battlefield Park, 2011.

	Species	Number of Post-Metamorphic Detections	Number of Larval Detections	Species Total Detections
Anura	American Toad	3	0	3
	Fowler's Toad	12	0	12
	Anaxyrus species	1	0	1
	Cope's Gray Treefrog	4	0	4
	Southeastern Chorus Frog	2	0	2
	Spring Peeper	5	0	5
	Pseudacris species	1	0	1
	Pickerel Frog	3	0	3
	Green Frog	8	1	9
	Southern Leopard Frog	7	0	7
	Ranidae species	9	0	9
Caudata	Marbled Salamander	1	0	1
	Spotted/Northern Dusky Salamander	26	28	54
	Seal Salamander	1	0	1
	Southern Two-lined Salamander	1	1	2
	Three-lined Salamander	1	0	1
	Two- or Three-lined Salamander	0	32	32
	Slimy Salamander	15	0	15
	Red Salamander	1	15	16
	Total Detections	**101**	**77**	**178**

Appendix B. Distribution Maps for Amphibian Species Encountered

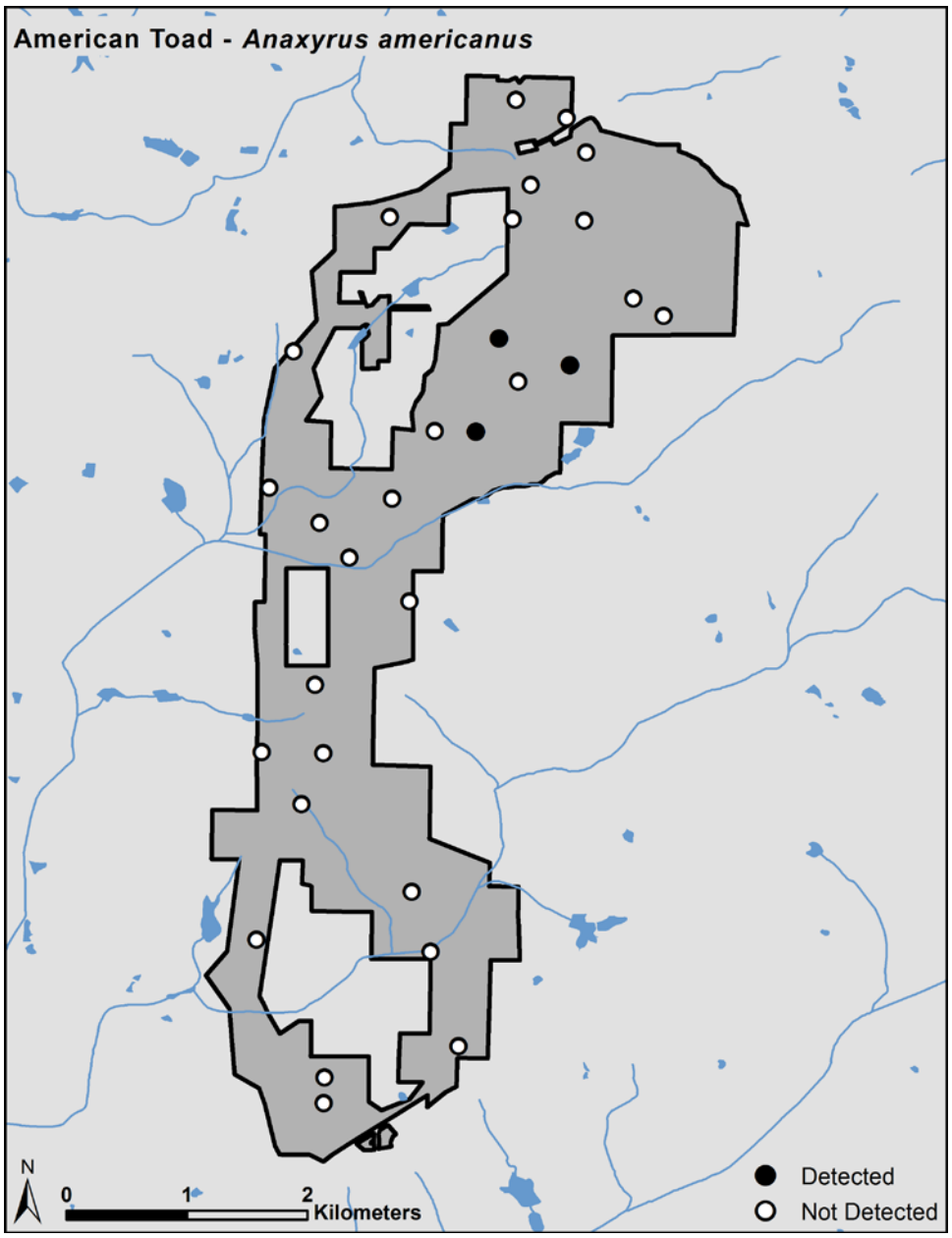

Figure B-1. Sampling locations where American Toad (*Anaxyrus americanus*) was detected at Kennesaw Mountain National Battlefield Park, 2011.

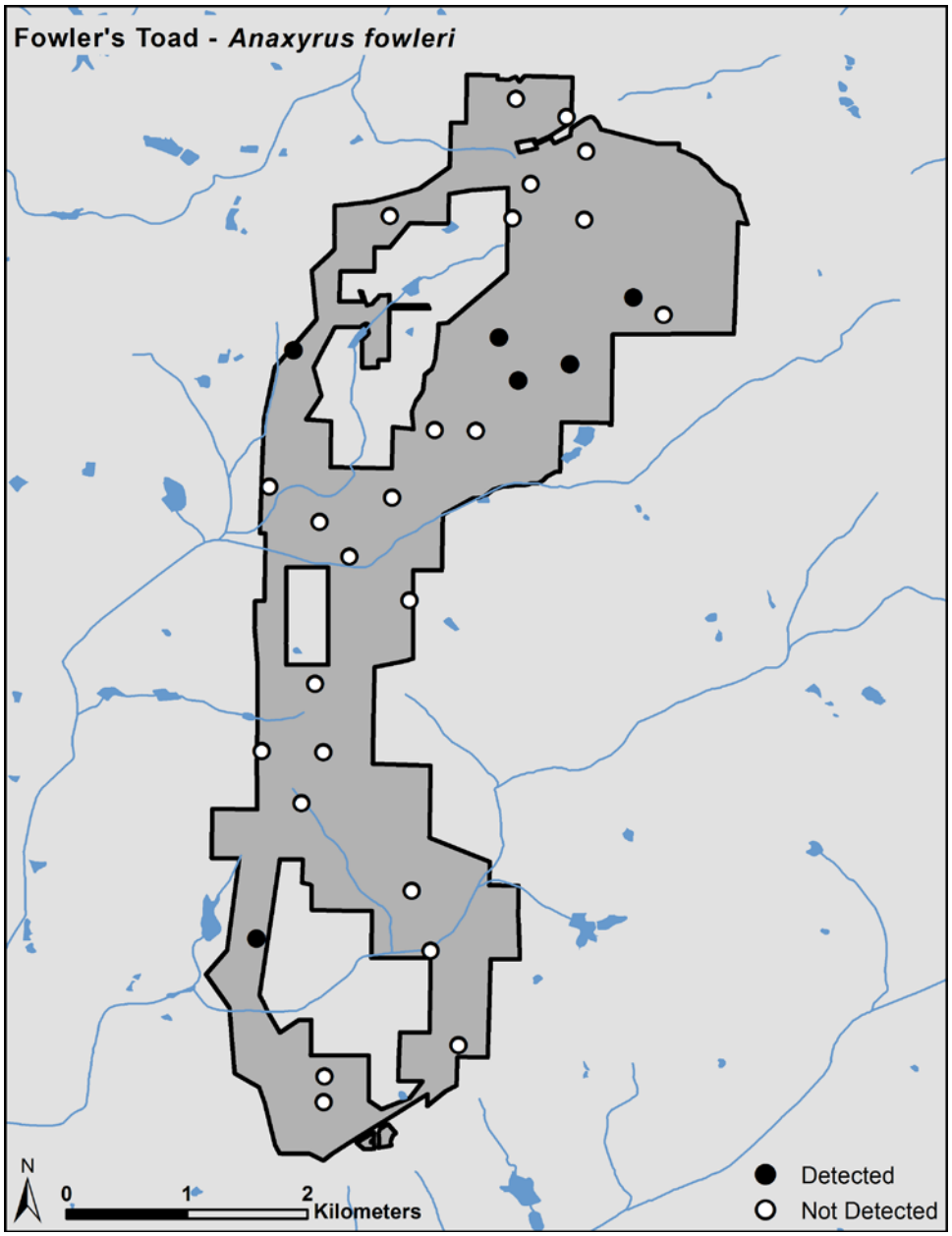

Figure B-2. Sampling locations where Fowler's Toad (*Anaxyrus fowleri*) was detected at Kennesaw Mountain National Battlefield Park, 2011.

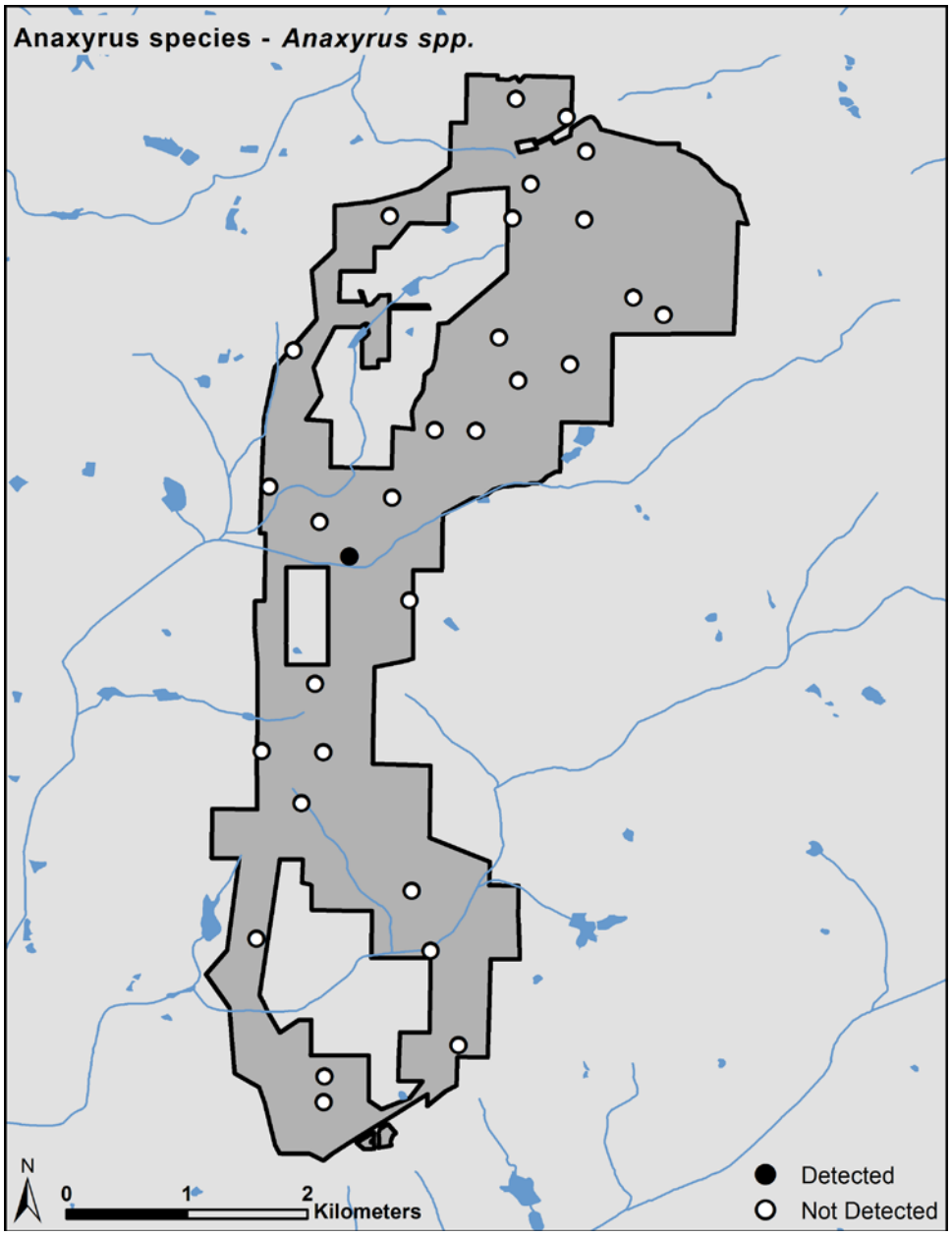

Figure B-3. Sampling location where a Toad species (*Anaxyrus* sp.) was detected at Kennesaw Mountain National Battlefield Park, 2011.

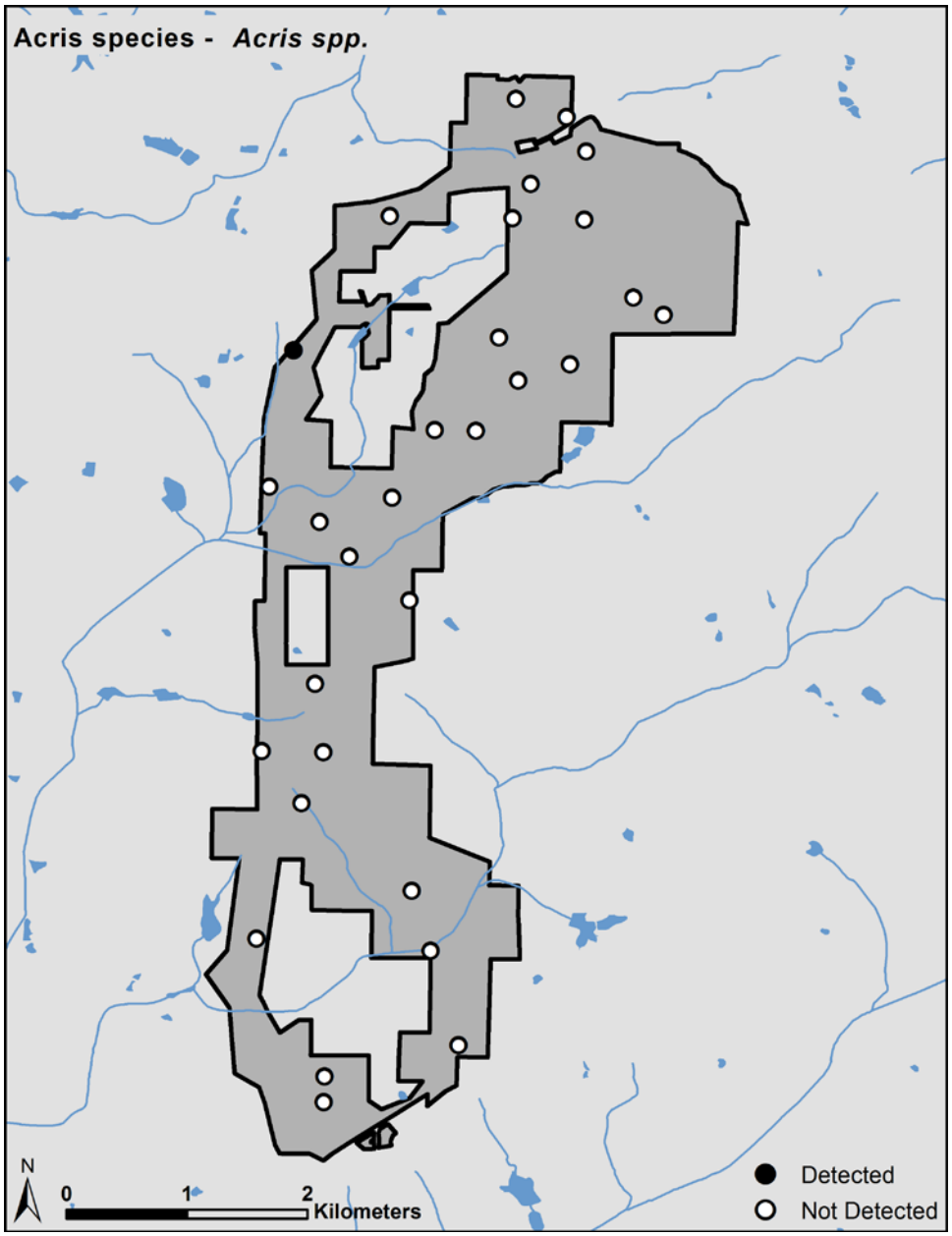

Figure B-4. Sampling location where Cricket Frog (*Acris crepitans* or *gryllus*) was detected at Kennesaw Mountain National Battlefield Park, 2011.

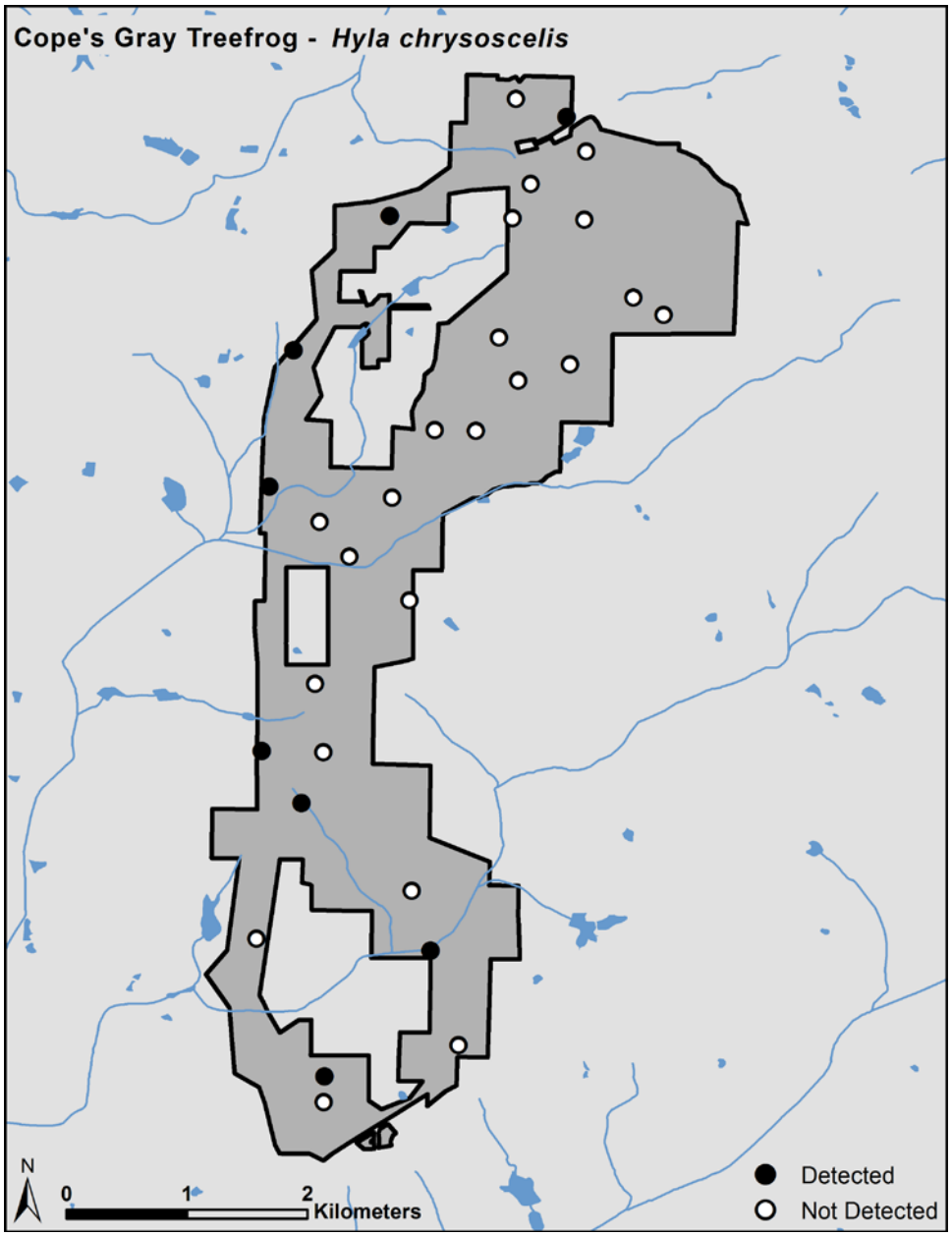

Figure B-5. Sampling locations where Cope's Gray Treefrog (*Hyla chrysoscelis*) was detected at Kennesaw Mountain National Battlefield Park, 2011.

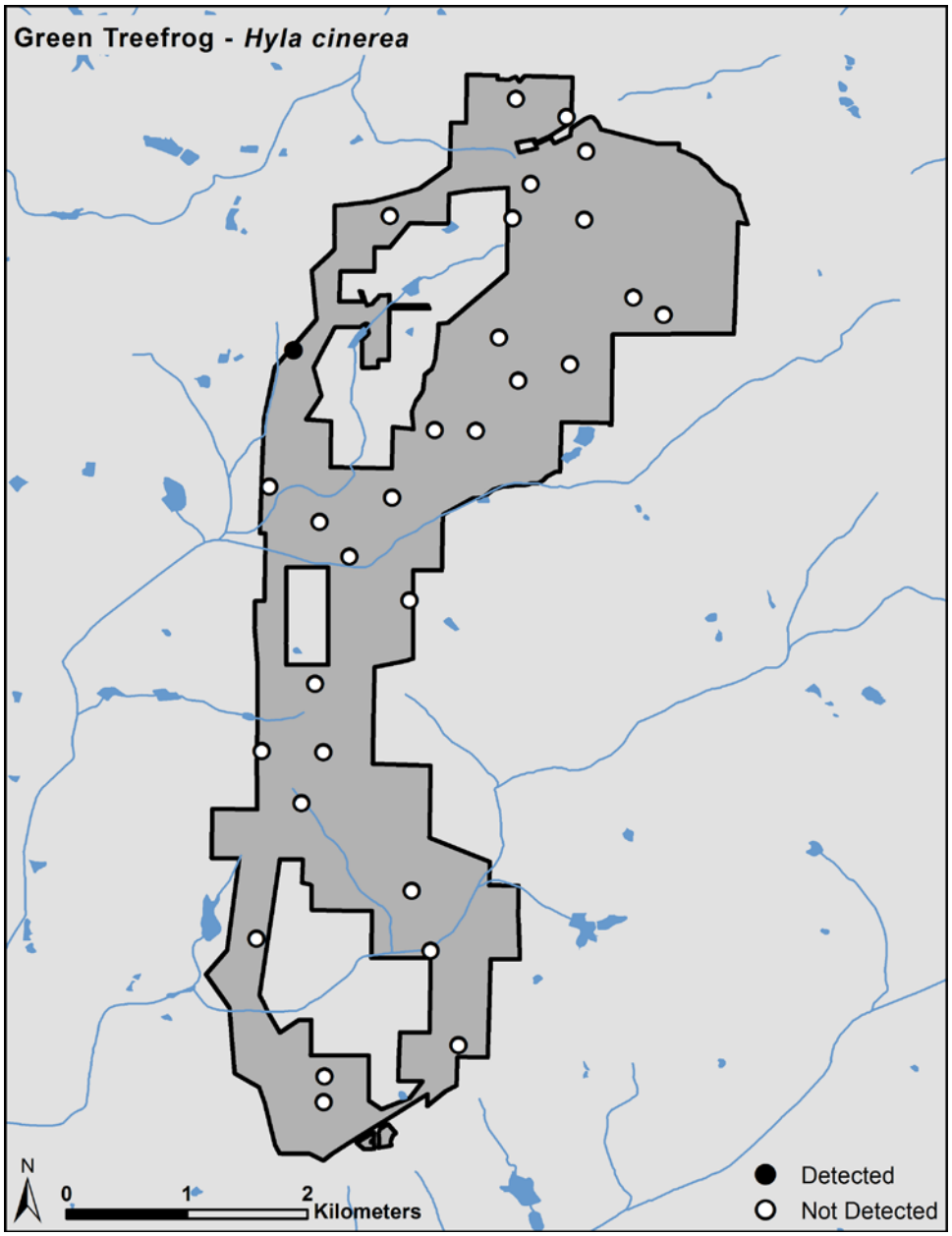

Figure B-6. Sampling location where Green Treefrog (*Hyla cinerea*) was detected at Kennesaw Mountain National Battlefield Park, 2011.

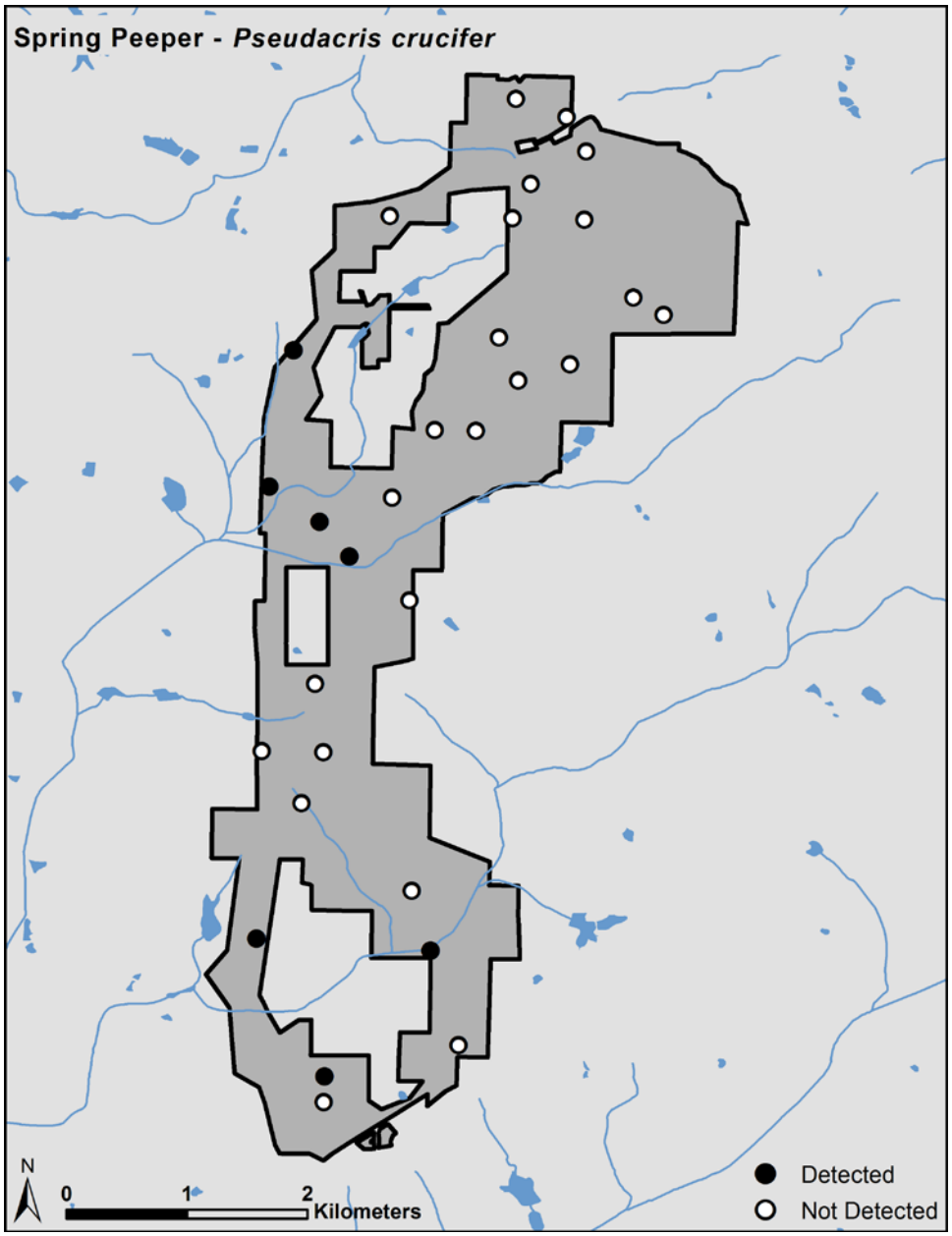

Figure B-7. Sampling locations where Spring Peeper (*Pseudacris crucifer*) was detected at Kennesaw Mountain National Battlefield Park, 2011.

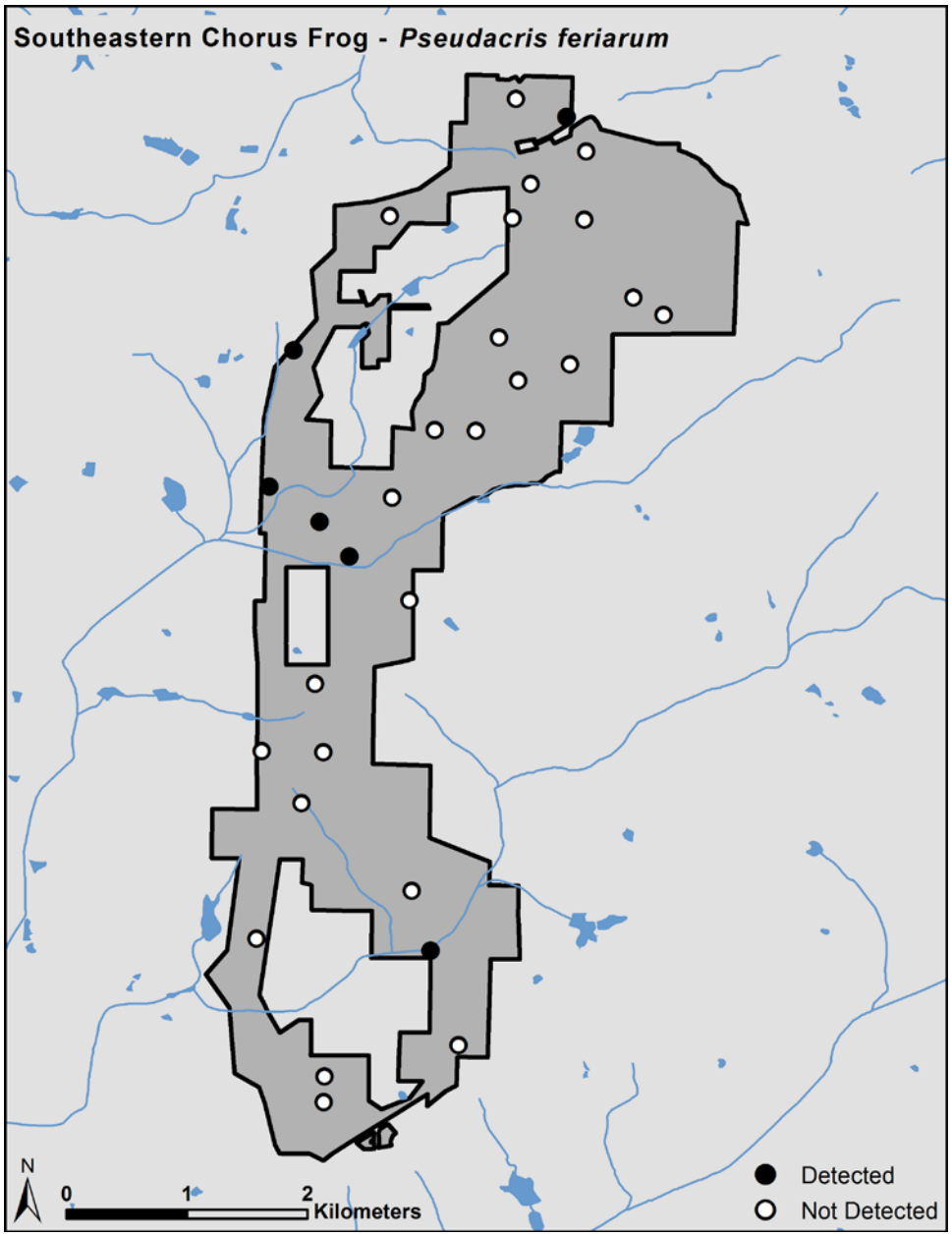

Figure B-8. Sampling locations where Southeastern (Upland) Chorus Frog (*Pseudacris feriarum*) was detected at Kennesaw Mountain National Battlefield Park, 2011.

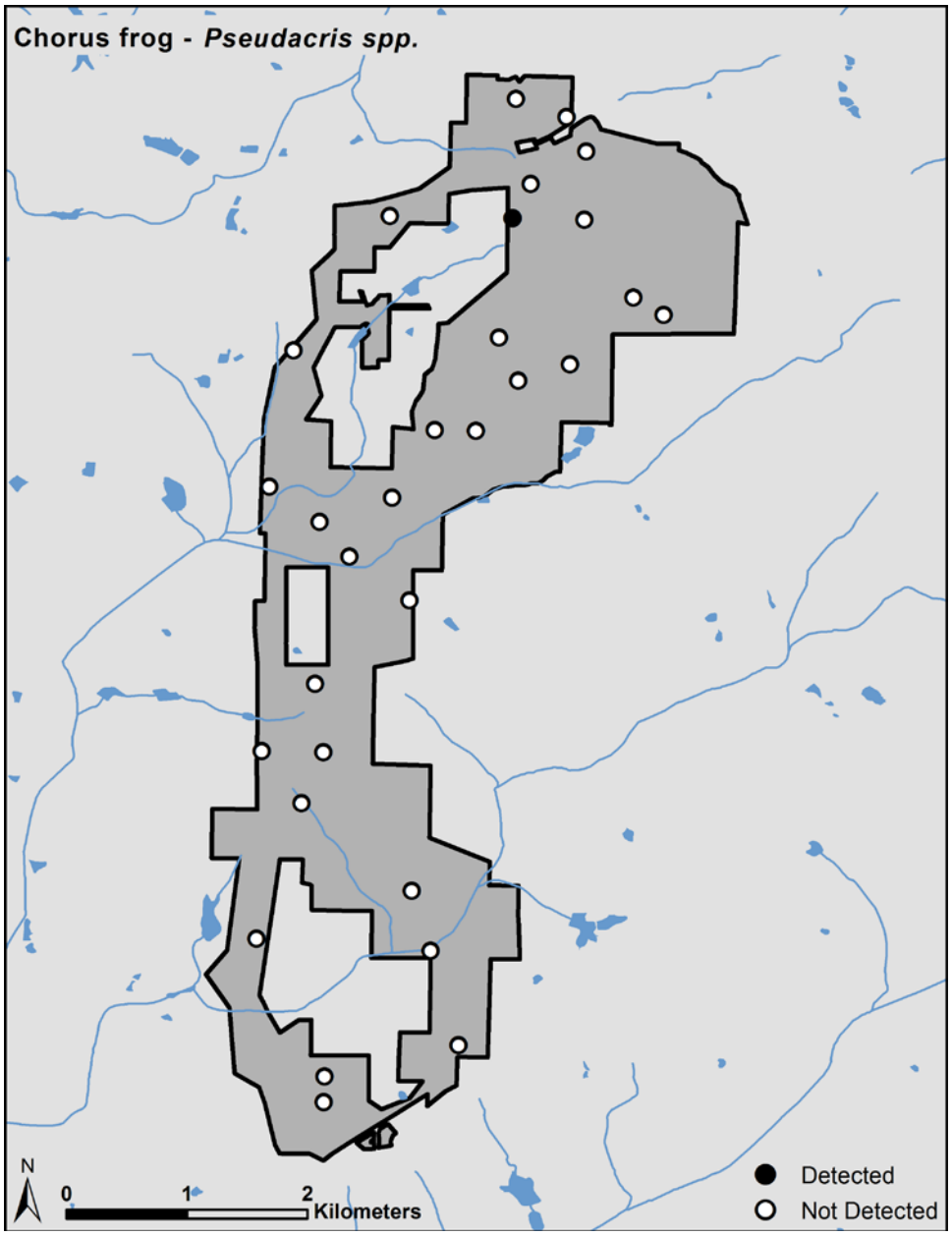

Figure B-9. Sampling location where a Chorus Frog species (*Pseudacris* sp.) was detected at Kennesaw Mountain National Battlefield Park, 2011.

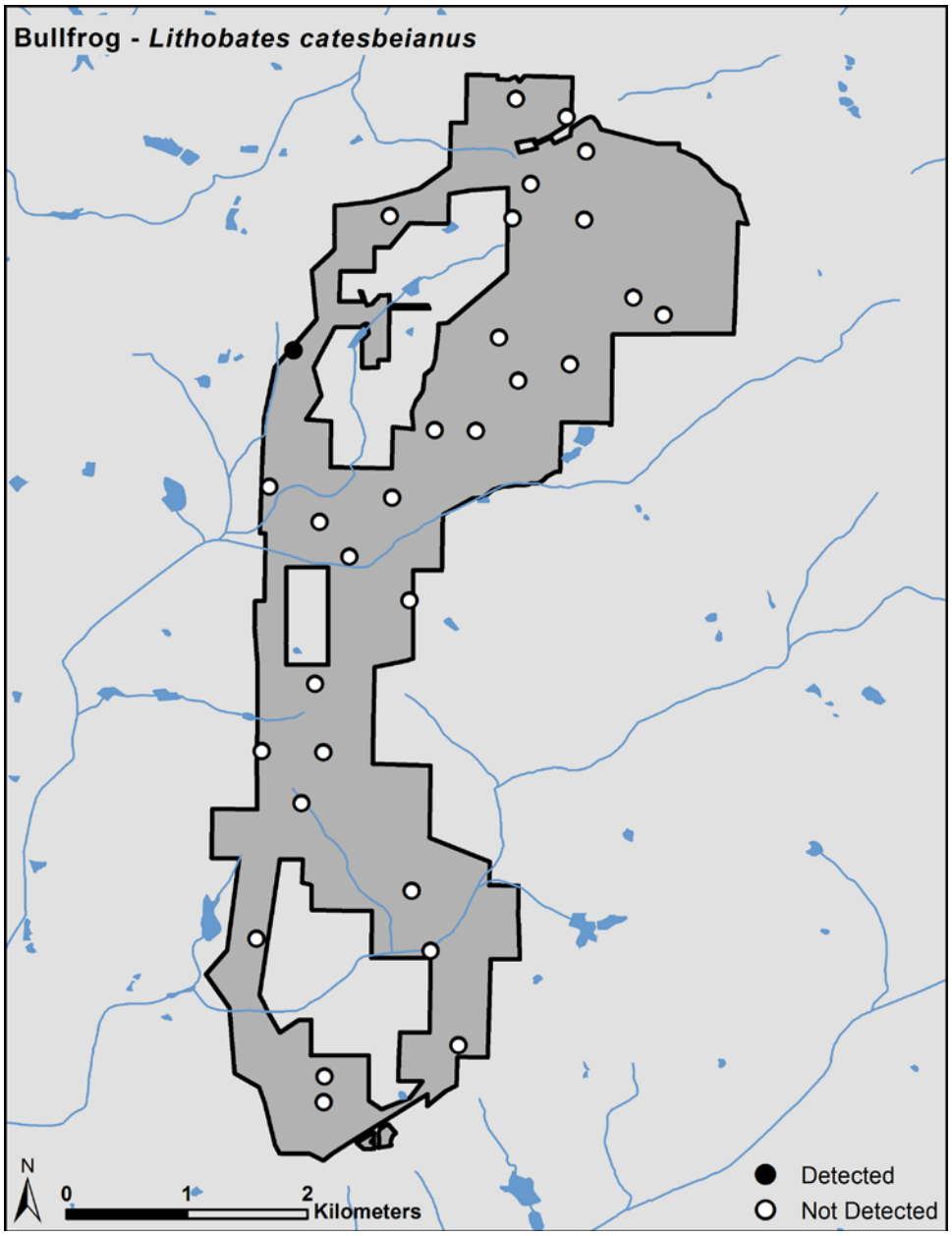

Figure B-10. Sampling location where Bullfrog (*Lithobates catesbeianus*) was detected at Kennesaw Mountain National Battlefield Park, 2011.

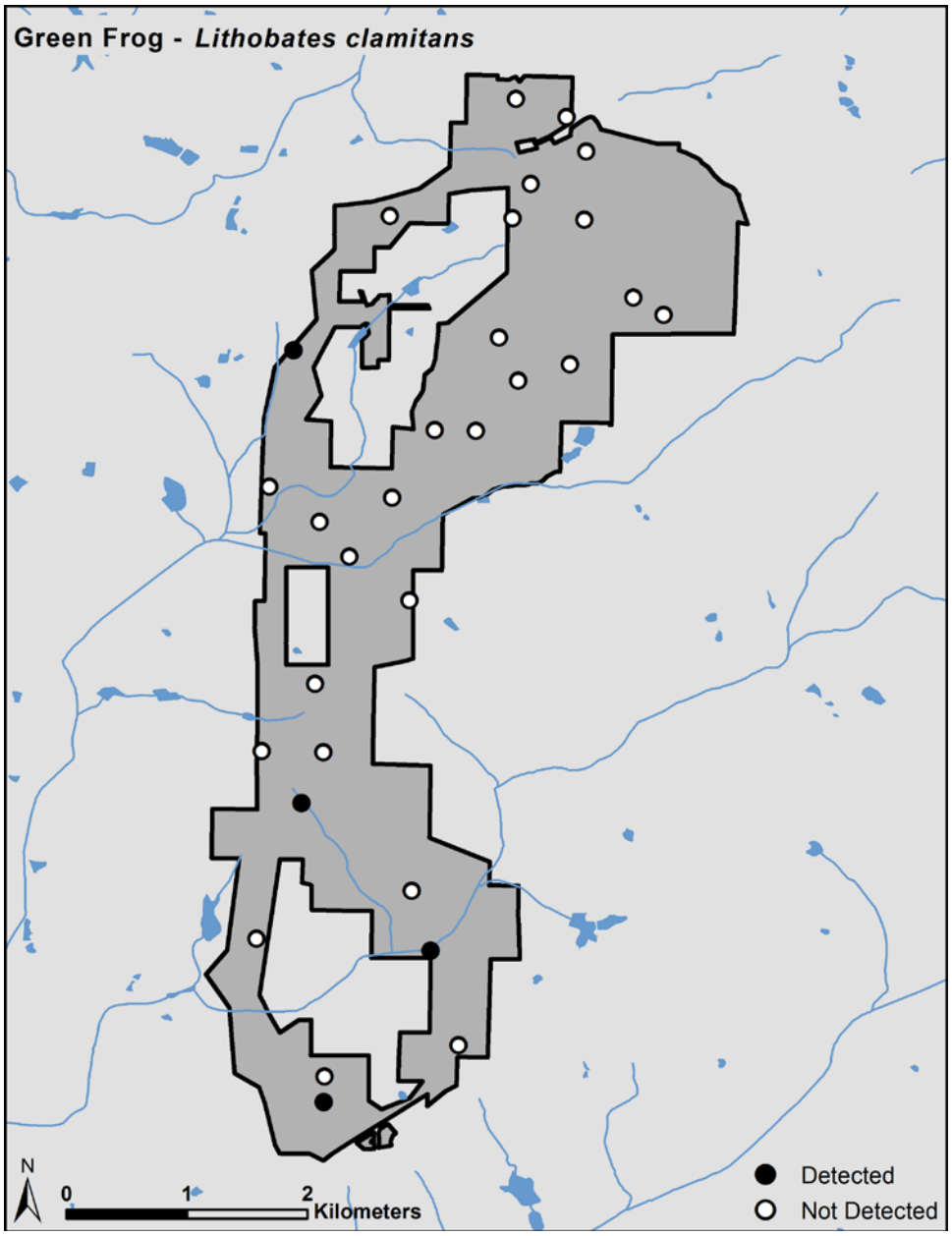

Figure B-11. Sampling locations where Green Frog (*Lithobates clamitans*) was detected at Kennesaw Mountain National Battlefield Park, 2011.

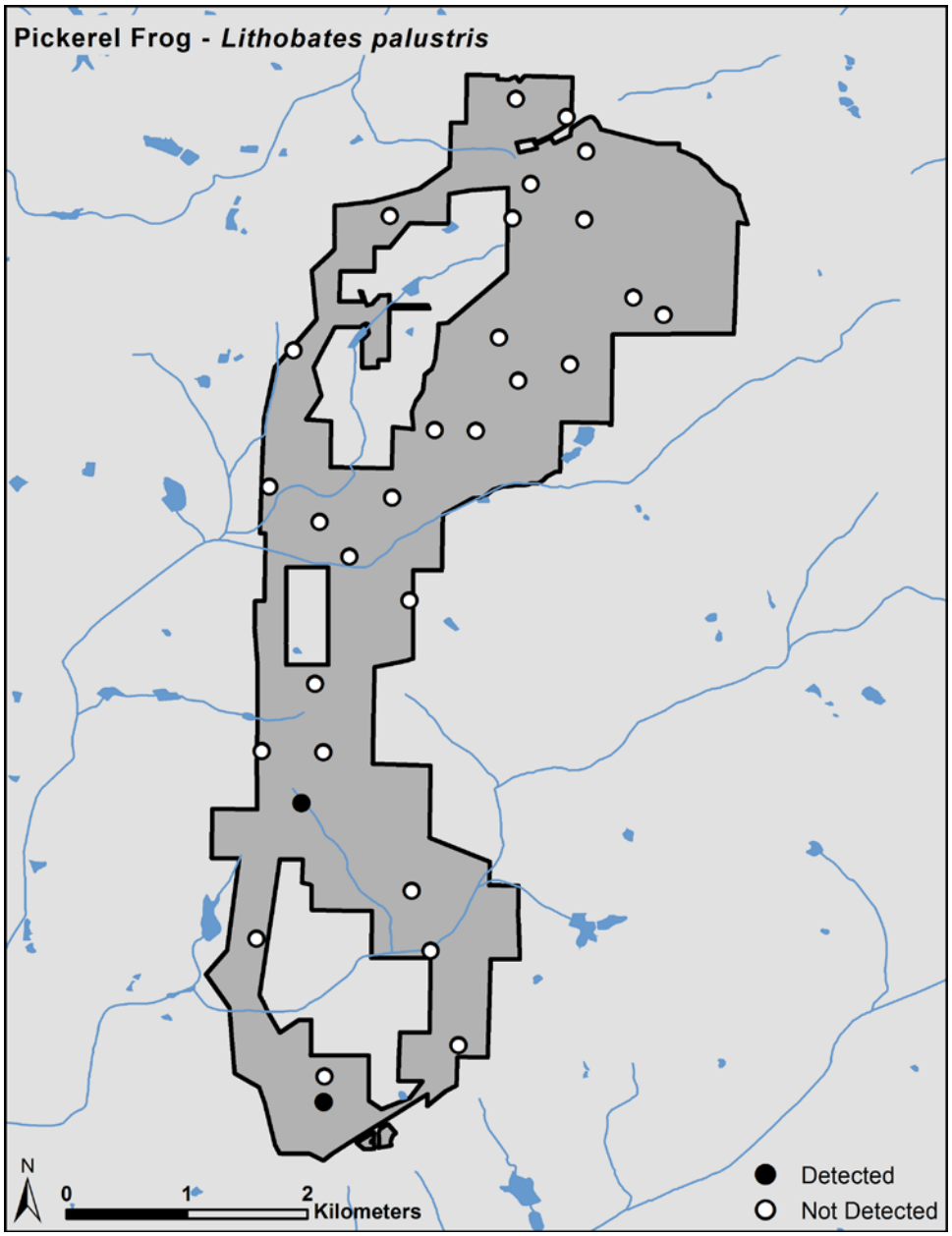

Figure B-12. Sampling locations where Pickerel Frog (*Lithobates palustris*) was detected at Kennesaw Mountain National Battlefield Park, 2011.

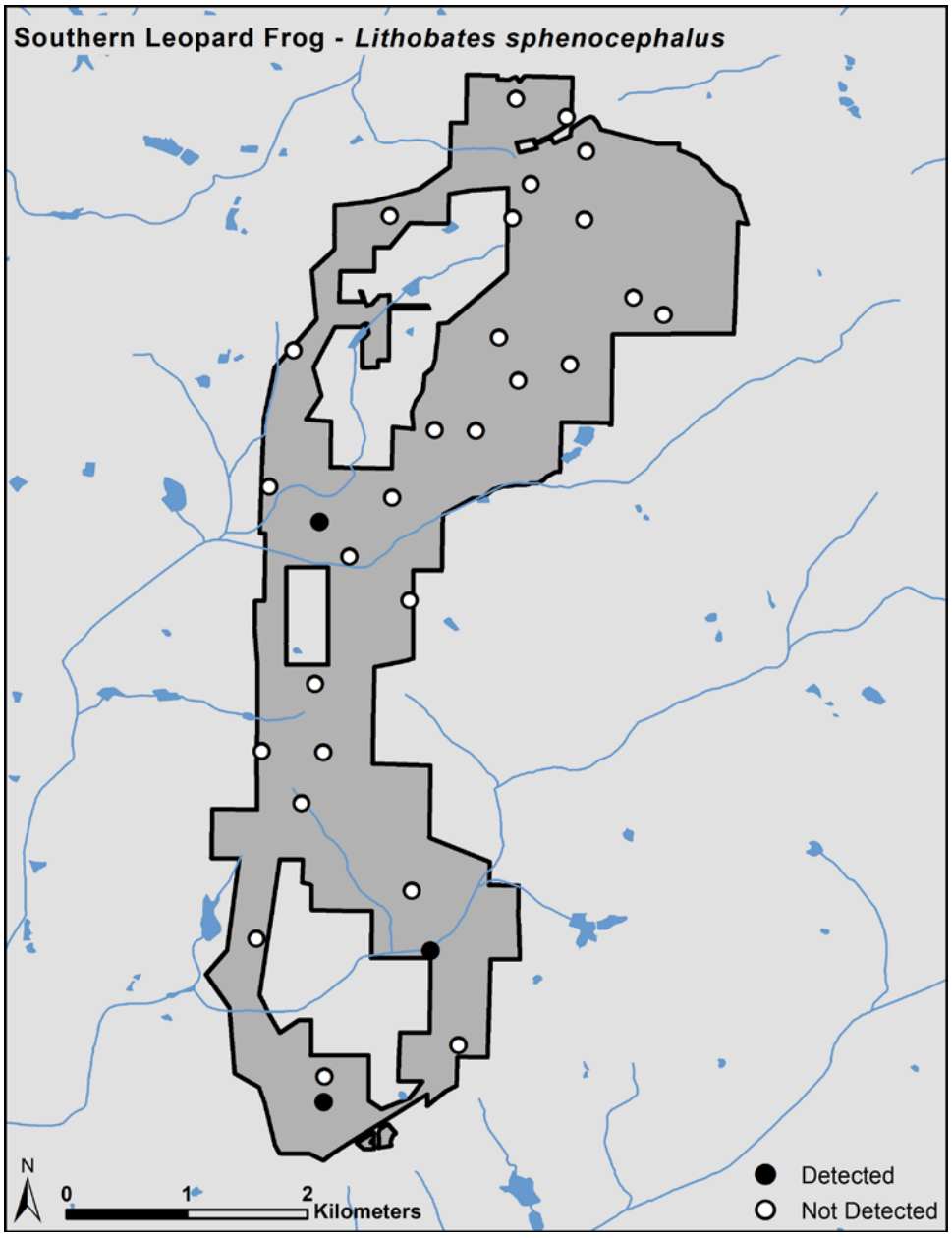

Figure B-13. Sampling locations where Southern Leopard Frog (*Lithobates sphenocephalus*) was detected at Kennesaw Mountain National Battlefield Park, 2011.

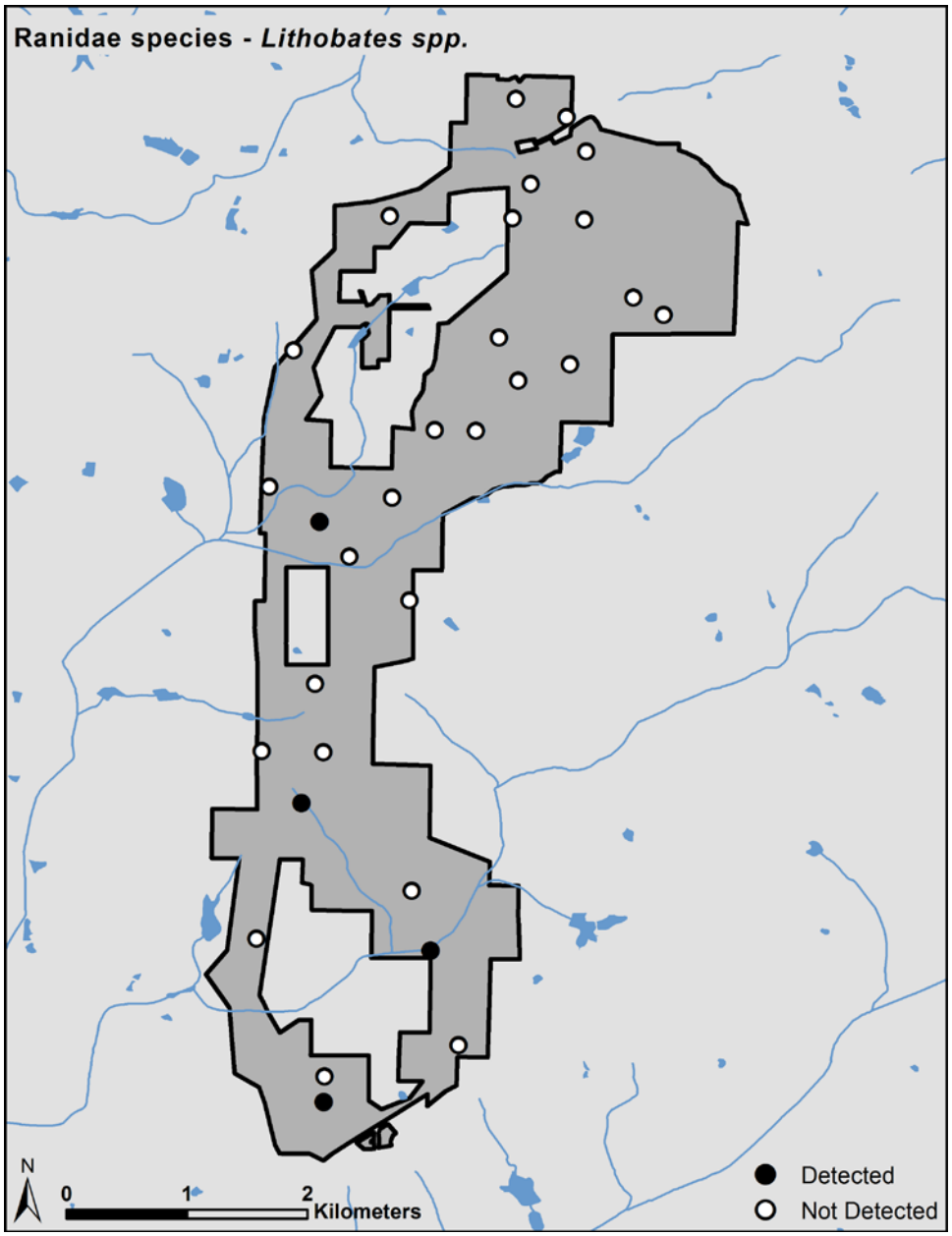

Figure B-14. Sampling locations where a *Ranid* species (*Ranidae* sp.) was detected at Kennesaw Mountain National Battlefield Park, 2011.

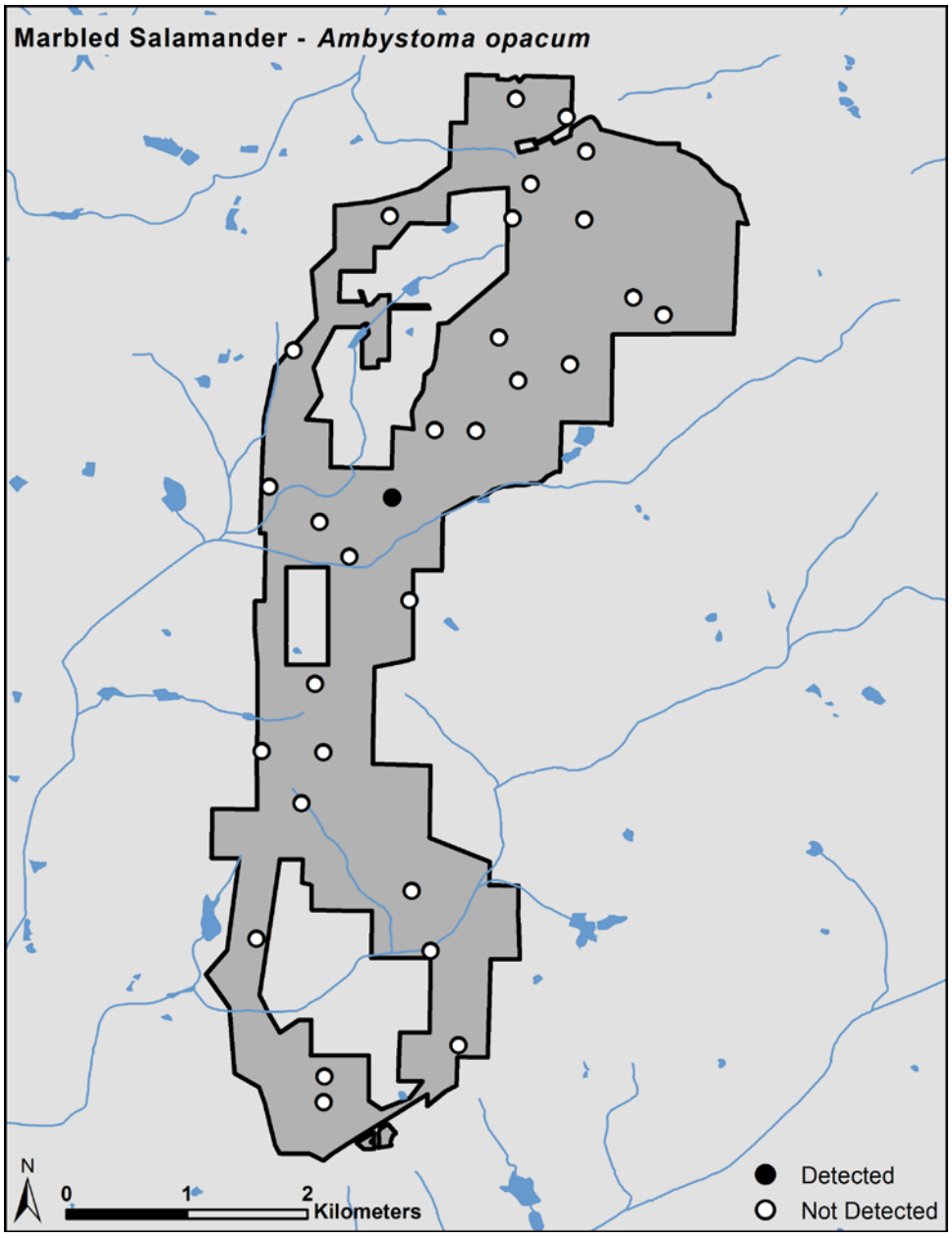

Figure B-15. Sampling location where Marbled Salamander (*Ambystoma opacum*) was detected at Kennesaw Mountain National Battlefield Park, 2011.

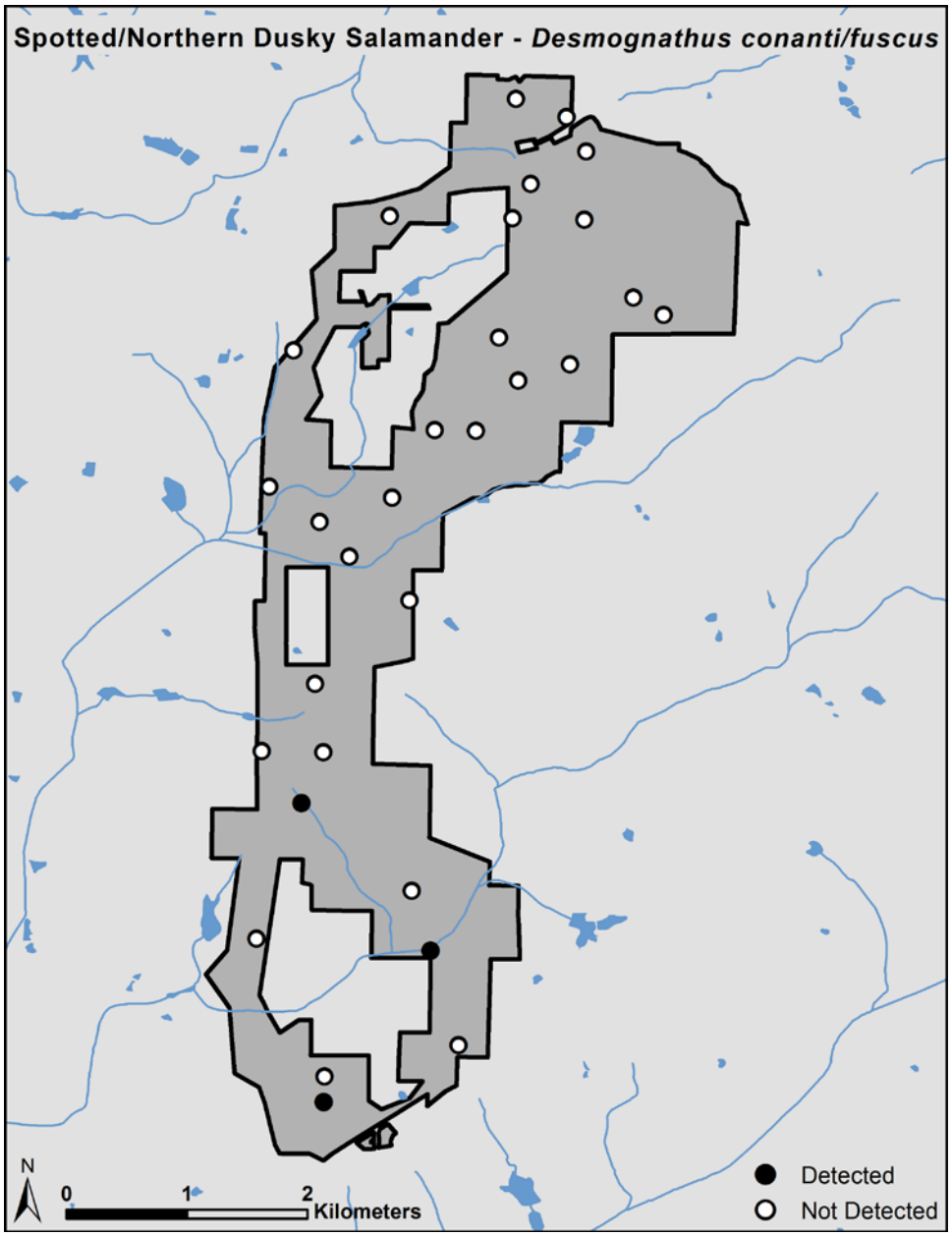

Figure B-16. Sampling locations where Spotted Dusky or Northern Dusky Salamander (*Desmognathus conanti* or *fuscus*) was detected at Kennesaw Mountain National Battlefield Park, 2011.

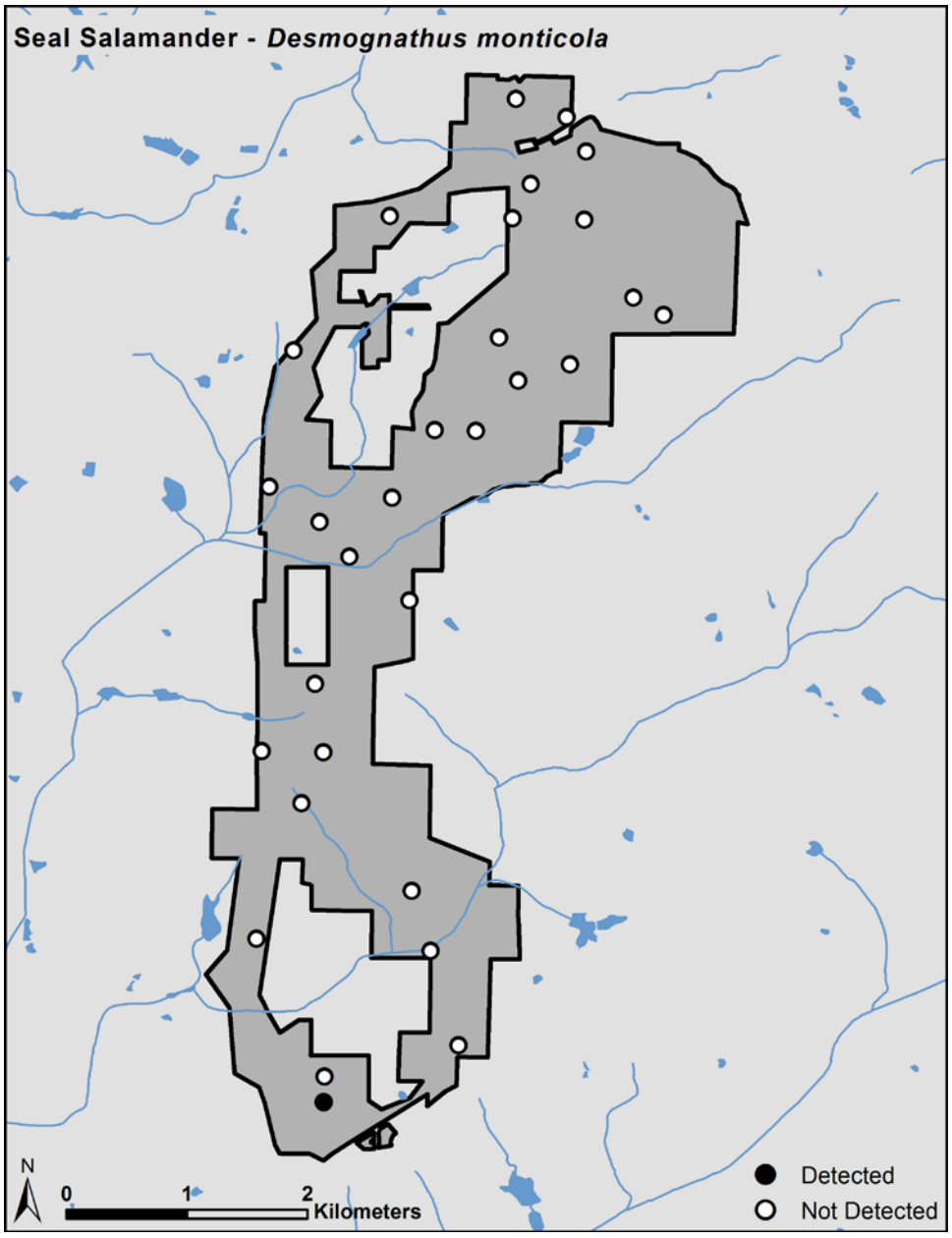

Figure B-17. Sampling location where Seal Salamander (*Desmognathus monticola*) was detected at Kennesaw Mountain National Battlefield Park, 2011.

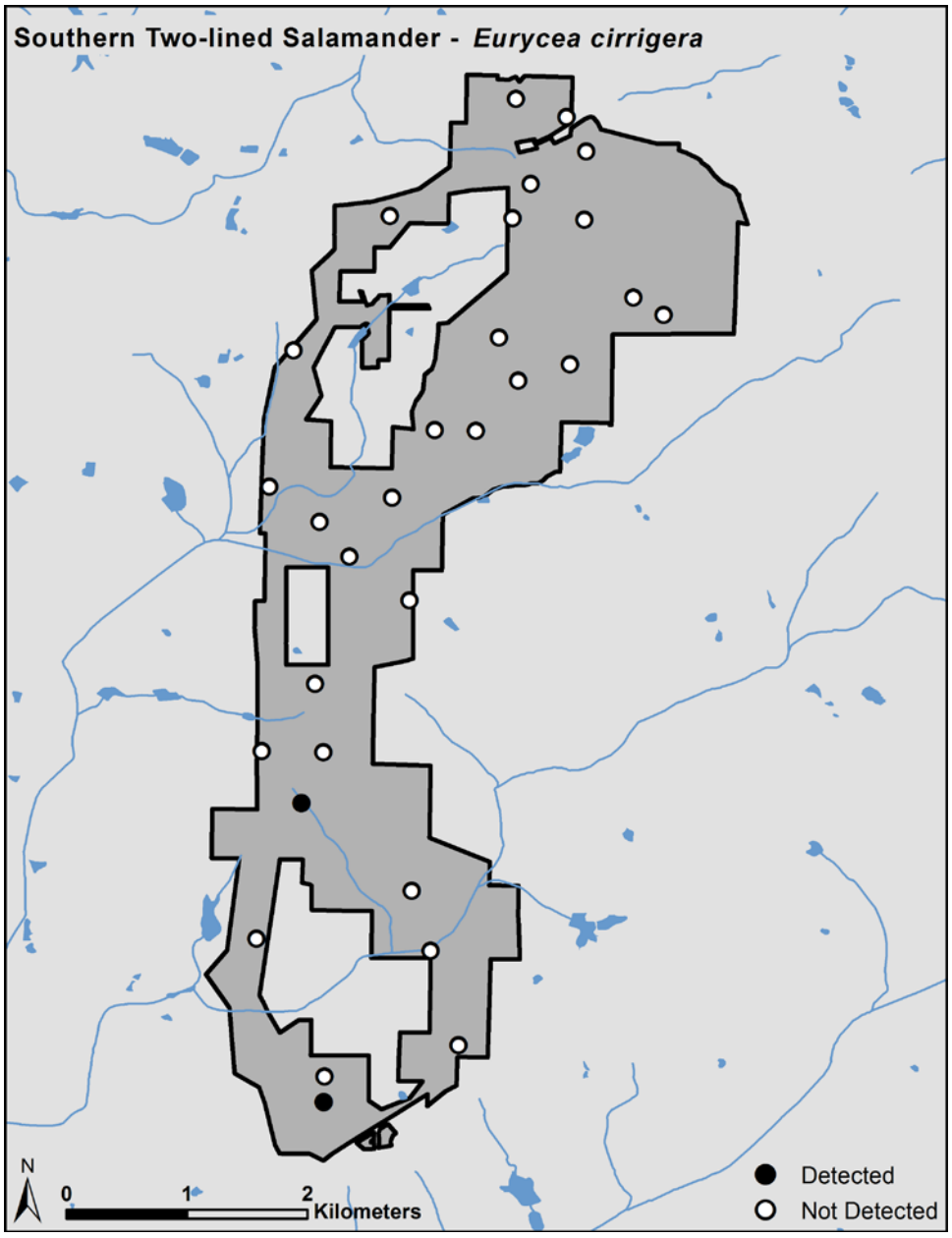

Figure B-18. Sampling locations where Southern Two-lined Salamander (*Eurycea cirrigera*) was detected at Kennesaw Mountain National Battlefield Park, 2011.

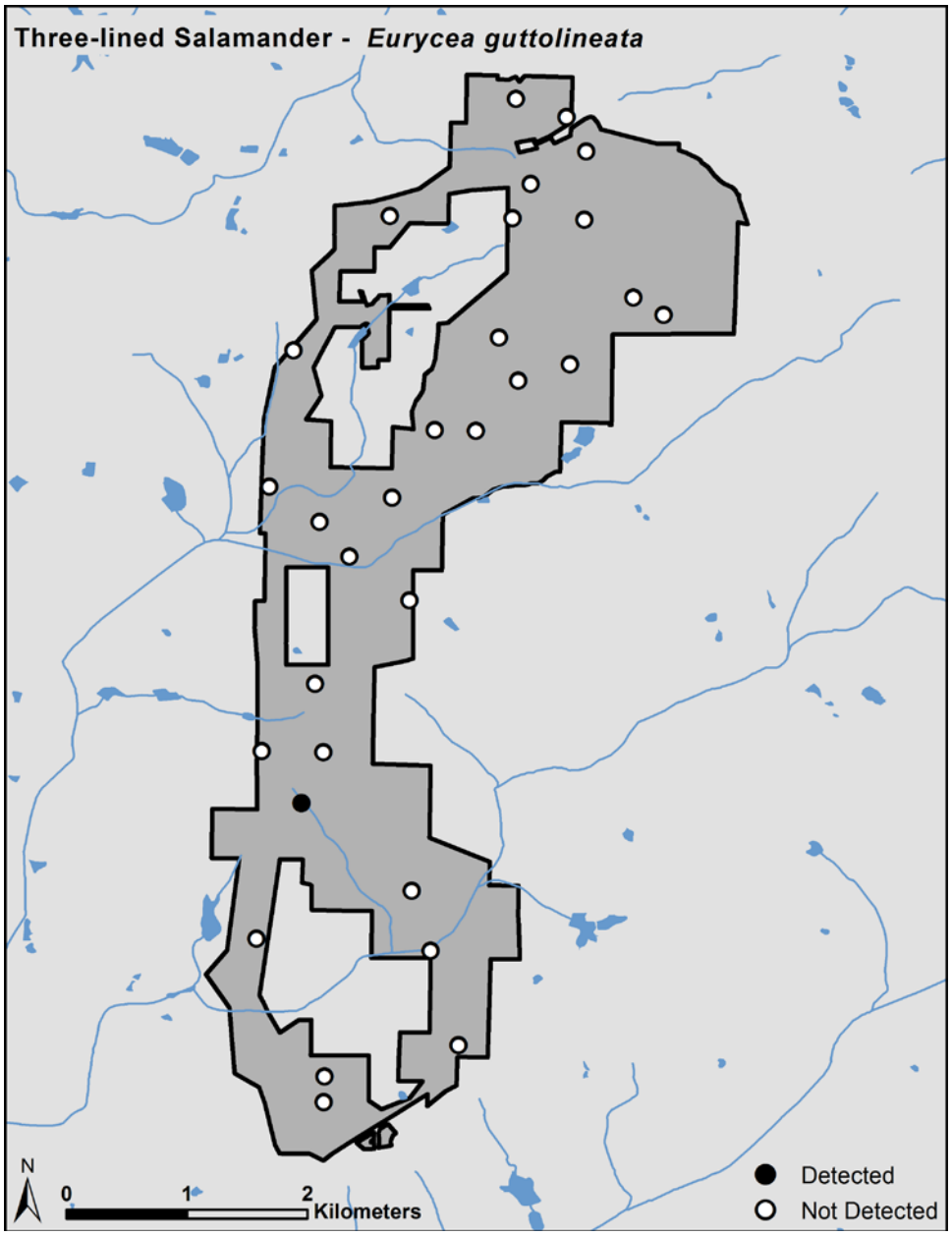

Figure B-19. Sampling location where Three-lined Salamander (*Eurycea guttolineata*) was detected at Kennesaw Mountain National Battlefield Park, 2011.

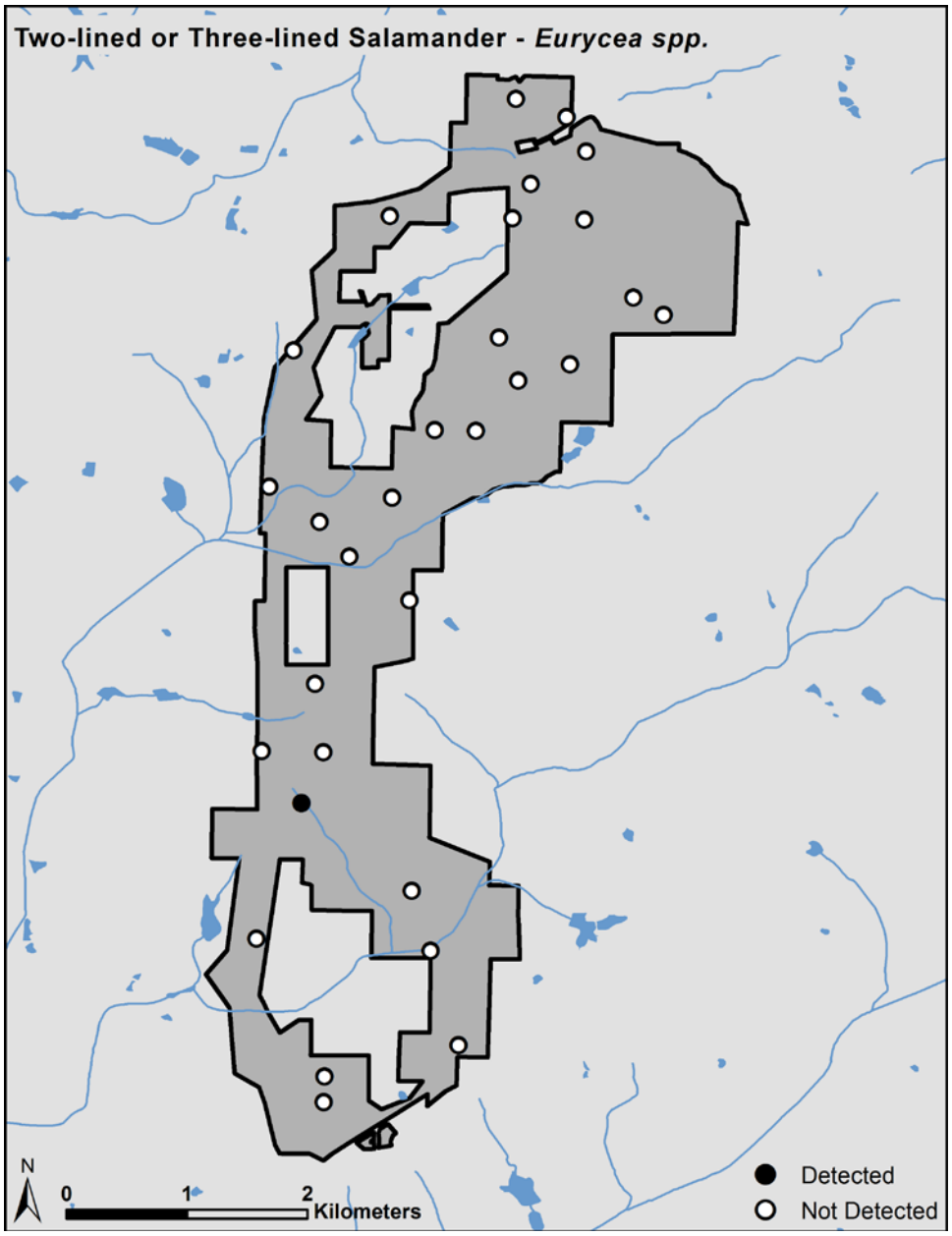

Figure B-20. Sampling location where Southern Two-lined or Three-lined Salamander larvae (*Eurycea cirrigera* or *guttolineata*) was detected at Kennesaw Mountain National Battlefield Park, 2011.

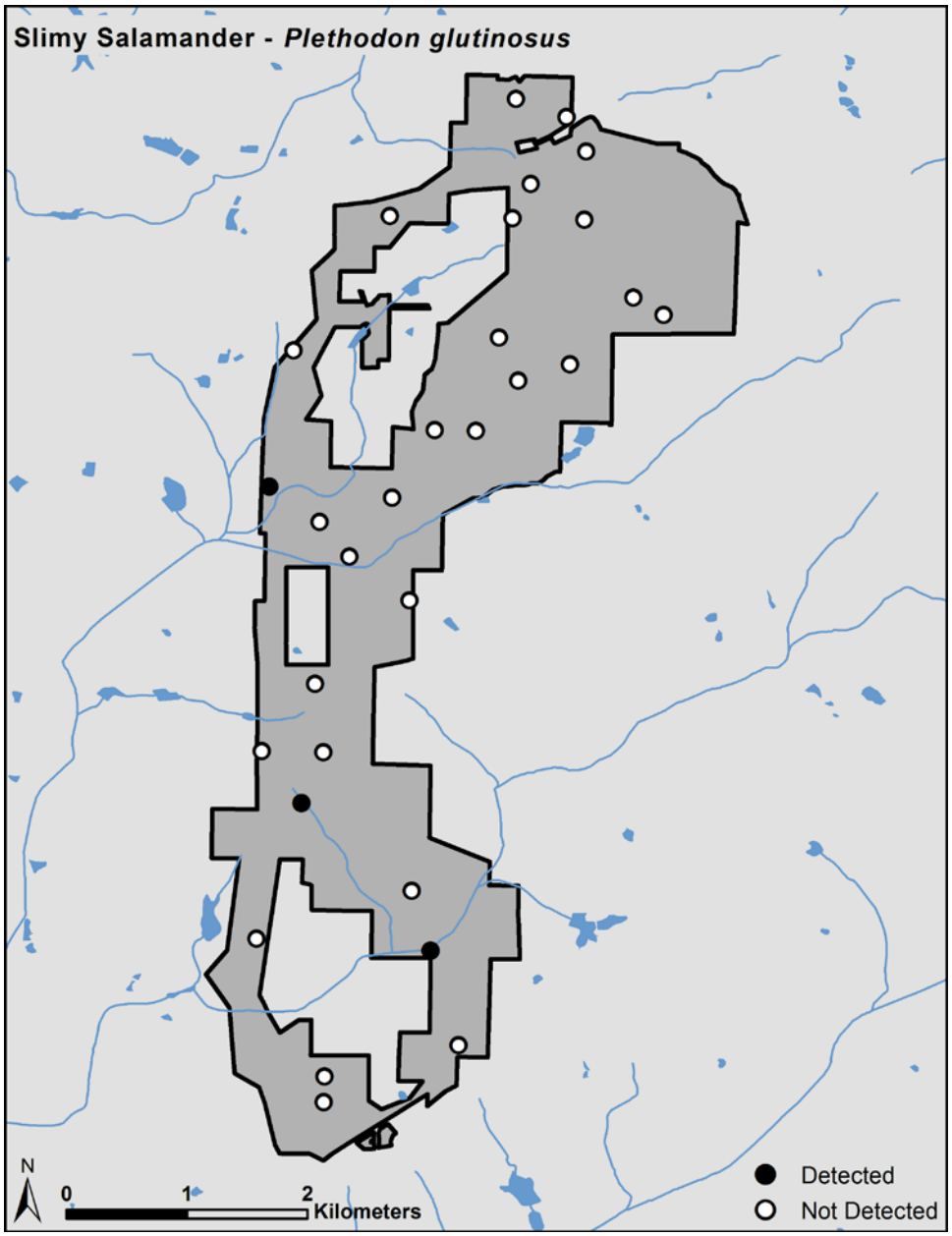

Figure B-21. Sampling locations where Slimy Salamander (*Plethodon glutinosis*) was detected at Kennesaw Mountain National Battlefield Park, 2011.

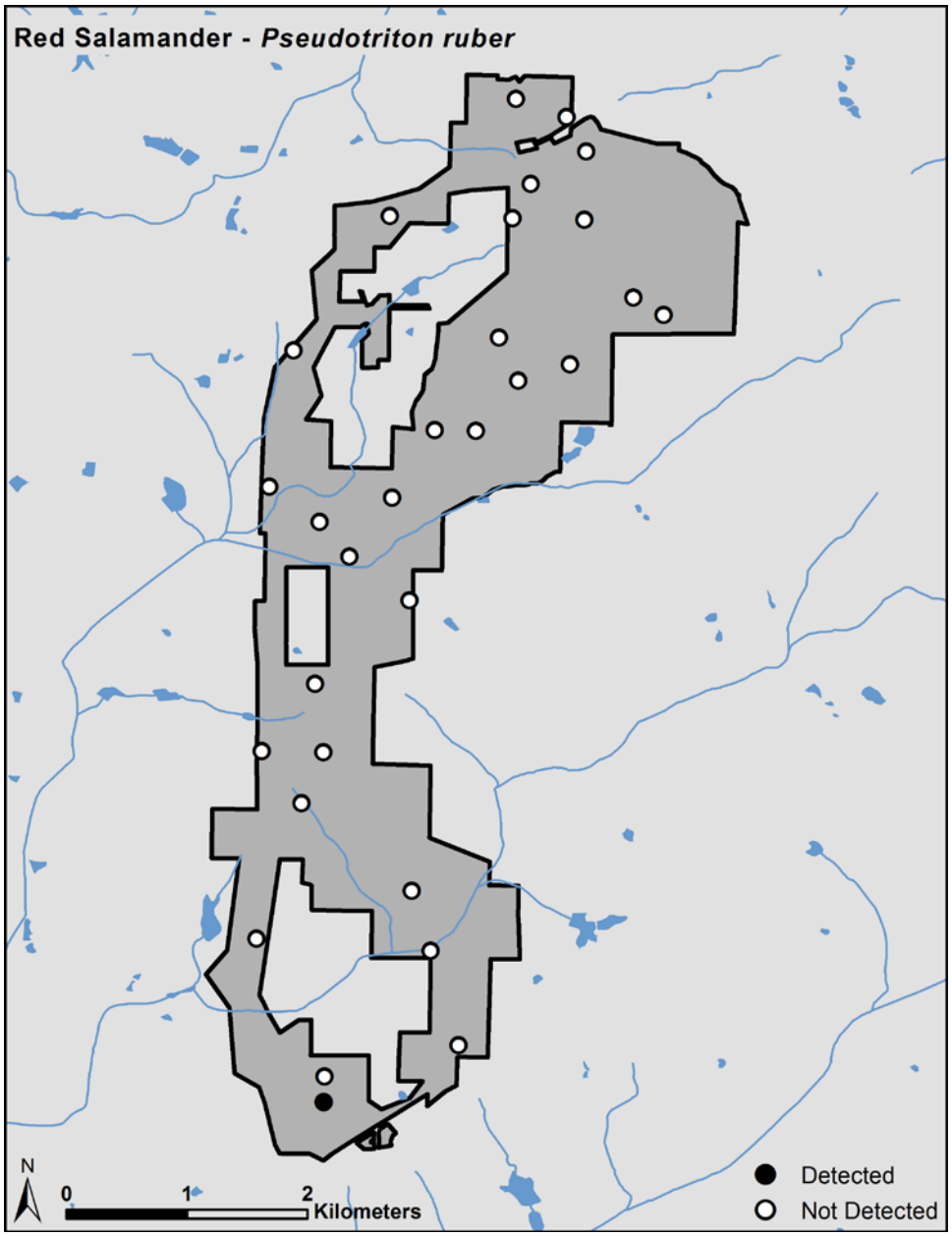

Figure B-22. Sampling location where Red Salamander (*Pseudotriton ruber*) was detected at Kennesaw Mountain National Battlefield Park, 2011.

Appendix C. Reptile Species Detection Data

Kennesaw Mountain National Battlefield Park has 28 known reptile species, consisting of 23 species in *Squamata* (e.g. lizards, snakes, geckos, and skinks), and 5 species in *Testudines* (turtles and tortoises) (Table C-1). As a result of our 2011 monitoring activities, three reptile species were added to the park species list; the smooth earth snake (*Virginia valeriae*), red-bellied water snake (*Nerodia erythrogaster erythrogaster*), and broad-headed skink (*Eumeces laticeps*) (Table C-3).

We detected 80 reptiles from 15 different taxa (species or genus) during VESs at KEMO in 2011, and six species composed nearly 70% of the detections (Figure C-1). Due to the difficulty in differentiating between two very similar species that have overlapping ranges at KEMO, the five-lined skink and the Southeastern five-lined skink (*Eumeces fasciatus* or *inexpectatus*) were grouped together for this analysis. The five-lined or Southeastern five-lined skink had the highest frequency of occurrence among reptiles, and was detected at 30% of the sampling locations (Table C-2). The worm snake (*Carphophis amoenus*) and the Eastern box turtle (*Terrapene carolina*) had the second highest frequency of occurrence, each found at 27% of the sampling locations, while the ground skink (*Scincella lateralis*) was detected at 23% of the locations. The five-lined or Southeastern five-lined skink and the worm snake had the highest relative abundances among reptiles, together accounting for nearly one-third of all reptile sightings (Figure C-1). The Eastern box turtle was the only *Testudines* detected, and accounted for 10% of all reptile sightings. No non-native reptile species were detected.

Table C-1. Reptile species known to occur at Kennesaw Mountain National Battlefield Park area based on the Park's certified species list (NPSpecies 2013) and those detected during this sampling effort.

Scientific Name	Common Name	NPSpecies	VES
Ophisaurus attenuatus	Slender Glass Lizard	X	
Carphophis amoenus	Worm Snake	X	X
Coluber constrictor	Black Racer	X	
Diadophis punctatus	Ring-necked Snake	X	X
Elaphe guttata	Corn Snake	X	
Elaphe obsoleta	Black Rat Snake	X	
Lampropeltis getula	Eastern Kingsnake	X	X
Nerodia erythrogaster	Plain-bellied Water Snake	X	
Nerodia erythrogaster erythrogaster	Red-bellied Water Snake		X
Nerodia sipedon	Northern Water Snake	X	
Opheodrys aestivus	Rough Green Snake	X	
Storeria dekayi	Dekay's Brown Snake	X	X
Storeria occipitomaculata	Red-bellied Snake	X	X
Thamnophis sirtalis	Garter Snake	X	X
Virginia valeriae	Smooth Earth Snake		X
Sceloporus undulatus	Eastern Fence Lizard	X	X
Anolis carolinensis	Green Anole	X	X
Eumeces fasciatus/ inexpectatus	SE Five-lined/Five-lined Skink	X	X
Eumeces laticeps	Broad-headed Skink		X
Scincella lateralis	Ground Skink	X	X
Aspidoscelis sexlineatus	Six-lined Racerunner	X	
Agkistrodon contortrix	Copperhead	X	
Chelydra serpentina serpentina	Eastern Snapping Turtle	X	
Chrysemys picta	Painted Turtle	X	
Terrapene carolina	Eastern Box Turtle	X	X
Trachemys scripta scripta	Yellow-bellied Slider	X	
Sternotherus odoratus	Common Musk Turtle	X	

Table C-2. Reptilian species or species sign detected at each sampling location at Kennesaw Mountain National Battlefield Park, 2011.

	Sampling Location																											
Species	1	2	3	5	6	7	8	9	10	11	13	14	15	16	17	18	19	20	21	22	23	24	26	27	28	29	30	alt1	alt2	alt3
Worm Snake			X	X		X																X		X			X	X	X	
Ring-necked Snake																						X	X							
Eastern Kingsnake															X															
Red-bellied Water Snake																X														
Nerodia sp.							X																							
Dekay's Brown Snake																											X			
Red-bellied Snake												X		X													X			
Garter Snake																													X	
Smooth Earth Snake														X			X					X								
Eastern Fence Lizard														X													X			X
Green Anole														X			X					X								
Green Anole Egg							X							X													X			
Southeastern Five-lined or Five-lined Skink	X		X		X					X							X				X	X		X	X					
Broad-headed Skink							X																							
Eumeces sp.																												X		
Ground Skink					X						X	X		X			X						X							X
Colubridae sp. Skin																	X									X				
Colubridae sp. Egg														X																
Eastern Box Turtle		X					X		X				X			X	X				X							X		

Table C-3. New reptile species detected at Kennesaw Mountain National Battlefield Park in 2011 and recommended NPSpecies classifications.

Scientific Name	Common Name	Abundance	Residency	Nativity	Pest	Management Priority	Exploitation Concerns
Eumeces laticeps	Broad-headed Skink	Unknown	Resident	Native	No	No	No
Nerodia erythrogaster erythrogaster	Red-bellied Water Snake	Unknown	Resident	Native	No	No	No
Virginia valeriae	Smooth Earth Snake	Unknown	Resident	Native	No	No	No

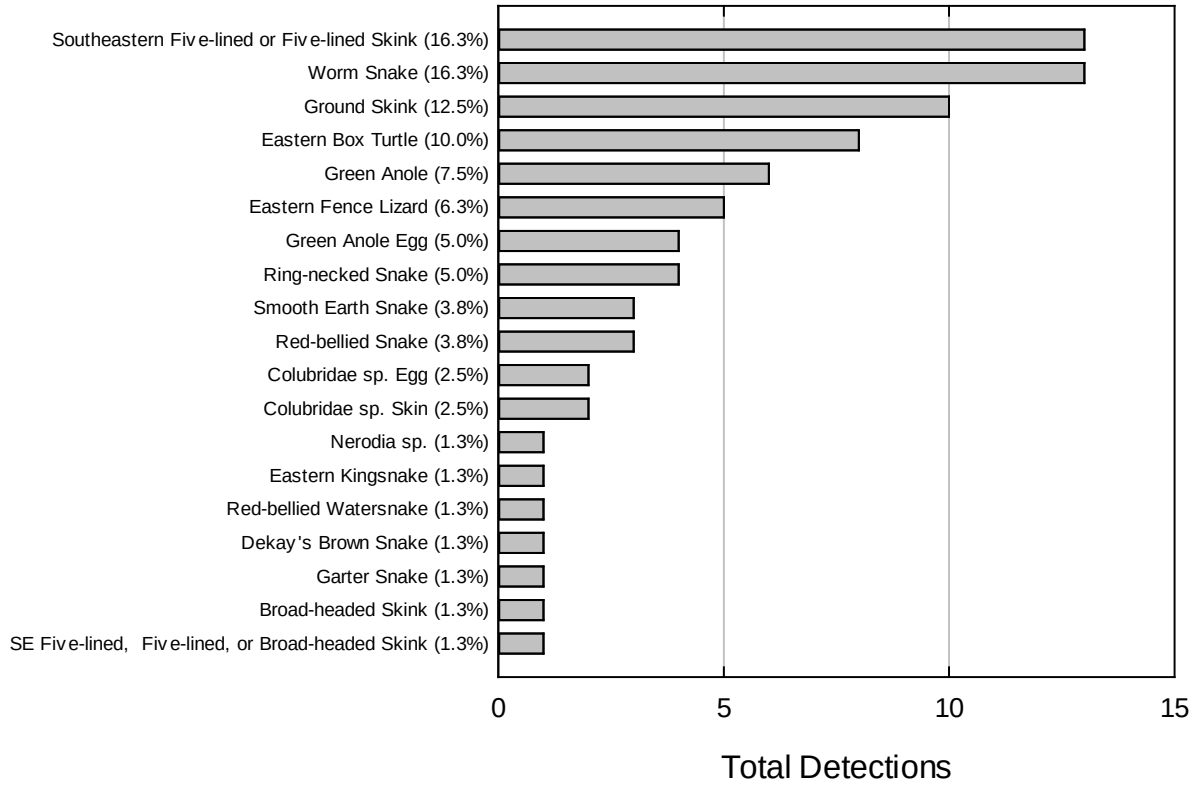

Figure C-1. Number of individual reptiles and reptile signs detected and percent species composition during visual encounter surveys at Kennesaw Mountain National Battlefield Park, 2011. Based on n=80 detections.