



Vocal Anuran Community Monitoring: 2017 Data Summary

Michael C. Parrish¹ and Lily H. Martin²

¹ Southeast Coast Network, NPS, 135 Phoenix Road, Athens, Georgia 30605

¹ <https://orcid.org/0000-0001-8475-3699>

² <https://orcid.org/0009-0009-7895-3956>

Overview

Amphibian populations have declined in North America and many other areas around the world. A variety of factors have contributed to these population declines and localized extinctions, including: anthropogenic habitat conversion and degradation, introduced non-native species, water and air pollution, disease, and altered surface water conditions (Collins and Storfer 2003; Muths et al. 2012). Partly due to their complex life cycles, which generally include an aquatic larval stage followed by an adult terrestrial phase, amphibians are often sensitive to perturbations of environmental conditions. Throughout their life cycle, amphibians rely heavily on availability of fresh, clean water to survive and successfully reproduce. Even apparently minor disruptions of the aquatic or terrestrial environments upon which amphibians depend may substantially impact the survival, reproduction, and persistence of a species. Many amphibian species in the United States, including those for which there is currently little or no conservation concern, may be experiencing widespread declines (Adams et al. 2013).

The southern region of the United States hosts the highest amphibian diversity in North America. The South is home to at least 45 species of anurans (i.e., frogs, toads, and treefrogs), which comprise 41% of the anuran species diversity of North America, north of Mexico (Dorcas and Gibbons 2008; SSAR 2017). Thirty-two species of anurans have been documented (NPS 2023) as occurring within the 15 park units monitored by the National Park Service's (NPS) Southeast Coast Network (SECN).

Anuran communities respond fairly quickly to environmental stressors or changes. Because of the conspicuous vocalization behavior exhibited by most species during breeding periods, anurans are relatively easy to detect and identify, compared with other amphibians. Changes in anuran species composition, richness, and distribution on the landscape may reflect alterations to underlying ecological conditions of park resources. In conjunction with other environmental measures (e.g., water quality, vegetation, fish assemblages), anuran assemblages can serve as effective indicators of ecological integrity (Zampella et al. 2006).



A bird-voiced treefrog (*Dryophytes avivoca*), one of several species detected during monitoring in 2017. NPS photo / NPgallery.

National parks comprise valuable protected landscapes where long-term monitoring can detect and track anuran population trends that can inform assessments of ecosystem integrity and sustainability (Halstead et al. 2022). Given the noteworthy diversity of amphibians in the Southeast, their sensitivity to environmental stressors, and their evident declines in recent decades, anuran communities represent a priority for SECN monitoring efforts. Our monitoring data contribute to understanding how park resources and natural communities respond to changing environmental conditions, informing park management decision making.

Objectives

This report summarizes data collected at Ocmulgee Mounds National Historical Park under the SECN Vocal Anuran Community Monitoring Protocol (Byrne et al. 2013). The data address the following protocol objectives:

1. Evaluate status of vocal anuran community species richness during the spring breeding season.
2. Assess vocal anuran occupancy and spatial distribution at sampling locations during the breeding season.

We use the term “community” to refer to an assemblage of species populations occurring together in time and space (Begon et al. 1986) and consider the vocal anuran species assemblage within the park as a *de facto* community (Byrne et al. 2013).

Significant Results

This brief summarizes data collected in 2017 at Ocmulgee Mounds National Historical Park during implementation of the Southeast Coast Network's Vocal Anuran Community Monitoring Protocol (Byrne et al. 2013).

- Automated recording devices (ARDs) captured anuran (i.e., frog, toad, and treefrog) vocalizations from March 30 to July 17 at 20 spatially-balanced random sampling locations.
- We extracted 16,902 potential audio signals from 13,068 minutes of audio recordings. We manually reviewed a systematically selected subset of 2,672 (15.8%) of the extracted signals and classified to species any identifiable anuran vocalizations found within that subset.
- We identified 11 native species of anurans, each of which was previously documented at the park (observations of two species of cricket frogs (genus *Acris*) were lumped due to call similarity). No non-native anurans were detected.
- Anurans were observed at 10 of 20 sampled locations.
- The most frequently detected species were green treefrog (*Dryophytes cinereus*), southern toad (*Anaxyrus terrestris*), and bird-voiced treefrog (*Dryophytes avivoca*), which respectively occurred at 40%, 30%, and 30% of permanent sampling locations.
- The next scheduled sampling of anuran communities at this park was in 2022.

Visit the NPS data store at the Integrated Resource Management Application portal for:

- [Data summary brief:](https://irma.nps.gov/DataStore/Reference/Profile/2294566) (https://irma.nps.gov/DataStore/Reference/Profile/2294566)
- [Species distribution maps:](https://irma.nps.gov/DataStore/Reference/Profile/2294565) (https://irma.nps.gov/DataStore/Reference/Profile/2294565)
- [Full dataset and metadata:](https://irma.nps.gov/DataStore/Reference/Profile/2299433) (https://irma.nps.gov/DataStore/Reference/Profile/2299433)



A Fowler's toad (*Anaxyrus fowleri*), one of several species detected during monitoring in 2017. NPS Photo / SECN staff.



A green treefrog (*Dryophytes cinereus*), one of several species detected during monitoring in 2017. NPS Photo / SECN staff.

Study Area

Ocmulgee Mounds National Historical Park is located in central Georgia, along the Fall Line, the biogeophysical transition zone between the Piedmont and the Southeastern Plains ecoregions. Parts of the park lie within the city limits of Macon, Georgia, and the Ocmulgee River borders the monument on the southern edge (Figure 1). A relatively intact corridor of native riparian vegetation connects the park with large tracts of natural and Federally-protected areas to the south.

Landforms at the park consist primarily of a sizeable floodplain and associated herbaceous wetlands and adjacent uplands. A large, maintained utility right-of-way and railroad track crosses the park in the northeast. The natural resources of the park have been heavily impacted by human influence. These include I-16, which essentially disconnects the river from its floodplain and alters the natural hydrologic patterns of the area. Threats to biological resources at the monument are primarily anthropogenic in origin, and include non-native species, air and water pollution, development, and other issues arising from the parks' proximity to Macon.

In 2017, the park comprised roughly 283 hectares (700 acres); however, the 2019 Dingell Act expanded the park's boundaries to almost 850 hectares (2,100 acres). Land acquisitions are currently ongoing.

Ocmulgee Mounds National Historical Park had 18 previously documented anuran species when sampling occurred in 2017 (Table 1; NPS 2023).



A southern toad (*Anaxyrus terrestris*), one of several species detected during monitoring in 2017. NPS Photo / Kristen Maxfield (NPGallery).



Audio Sampling Locations

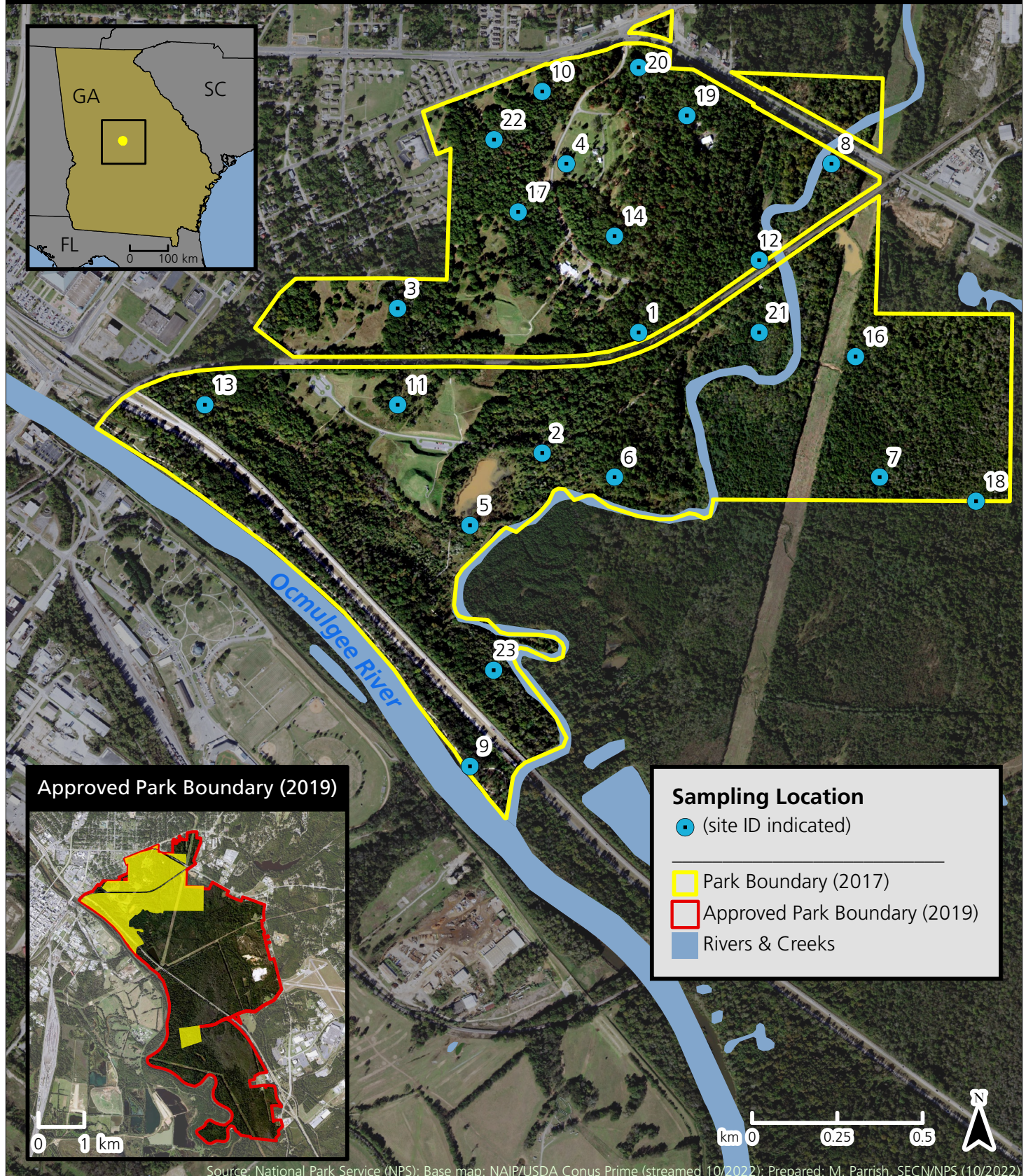


Figure 1. Permanent audio sampling locations ($n = 22$) at Ocmulgee Mounds National Historical Park. Sampling location ID numbers are indicated at each point.

Table 1. Anurans known to occur at Ocmulgee Mounds National Historical Park based upon records in NPSpecies (NPS 2023) and those detected during our 2017 sampling. Documented species indicated with "X."

Order	Family	Species	Authority	Common Name	NPSpecies (2023)	SECN Monitoring (2017)
Anura	Bufonidae	<i>Anaxyrus americanus</i>	Holbrook 1836	American toad	X	X
		<i>Anaxyrus fowleri</i>	Hinckley 1882	Fowler's toad	X	X
		<i>Anaxyrus terrestris</i>	Bonnaterre 1789	Southern toad	X	X
	Hylidae	<i>Acris</i> spp. ¹	Duméril and Bibron 1841	Cricket frog spp. ¹	n/a	X ¹
		<i>Acris crepitans</i>	Baird 1854	Northern cricket frog	X	n/a
		<i>Acris gryllus</i>	LeConte 1825	Southern cricket frog	X	n/a
		<i>Dryophytes avivoca</i>	Viosca 1928	bird-voiced treefrog	X	X
		<i>Dryophytes chrysoscelis</i>	Cope 1880	Cope's gray treefrog	X	X
		<i>Dryophytes cinereus</i>	Schneider 1799	Green treefrog	X	X
		<i>Dryophytes squirellus</i>	Daudin 1800	Squirrel treefrog	X	X
		<i>Pseudacris crucifer</i>	Wied-Neuwied 1838	Spring peeper	X	X
		<i>Pseudacris feriarum</i>	Baird 1854	Upland chorus frog	X	–
		<i>Pseudacris nigrita</i>	LeConte 1825	Southern chorus frog	X	–
		<i>Pseudacris ornata</i>	Holbrook 1836	Ornate chorus frog	X	–
	Microhylidae	<i>Gastrophryne carolinensis</i>	Holbrook 1835	Eastern narrow-mouthed toad	X	X
	Ranidae	<i>Lithobates catesbeianus</i>	Shaw 1802	American bullfrog	X	–
		<i>Lithobates clamitans</i>	Latreille 1801	Green frog	X	–
		<i>Lithobates sphenoccephalus</i>	Cope 1886	Southern leopard frog	X	X
	Scaphiopodidae	<i>Scaphiopus holbrookii</i>	Harlan 1835	Eastern spadefoot	X	–

¹ Northern cricket frog and southern cricket frog could not be distinguished reliably by voice and any *Acris* spp. vocalizations were lumped by the Southeast Coast Network.

Methods

Sampling Design

Southeast Coast Network established a randomly-selected, spatially-balanced set of sample locations ($n = 22$) during an initial field season in 2014 (Figure 1). Our sample size was chosen based on considerations that included park size, hypothesized variability in wildlife populations, and logistics. Sample locations are permanent and are revisited on a three-year rotation. More comprehensive details regarding study design, data collection, and data analyses can be found in the SECN Vocal Anuran Community Monitoring Protocol (Byrne et al. 2013). This report pertains to 2017 sampling only.

Data Collection

In 2017, we deployed automated recording devices (ARDs) at 22 permanent sampling locations (Figure 1). Two units (at sites 07 and 09) subsequently experienced equipment failure, reducing our sample size to $n = 20$. Deployment and retrieval dates varied somewhat between ARDs, with deployments occurring between March 30 and April 11, and retrievals between June 22 and July 17. We programmed each ARD to record audio on every fourth night, in 30-second intervals every 10 minutes from 20:00 to 04:50, a total of 19 to 27 nights of sampling per ARD. Each ARD captured between 1,080 and 1,512 recordings (540 to 756 minutes of audio) during the recording period.

The ARDs were collected from the field after recording was completed and audio files were downloaded to a computer for classification and analyses.

Manual Classification of Recordings

It is not possible, given personnel constraints, to manually review all recordings for a park. Additionally, a full manual review of all audio recordings would not be an efficient use of resources, considering that a large proportion of the recordings do not contain signals of interest. We therefore began classification work by using computer program Kaleidoscope Pro (Wildlife Acoustics, Inc 2023) to automatically review all recordings at a sample location in the park and to extract as many signal detections as possible. Signal detections usually comprise natural or artificial acoustic departures from the background soundscape, and may include biological signals of interest (i.e., frog calls), biological signals not of interest (e.g., bird calls, insect noises, or human noises), natural environmental sounds not of interest (e.g., rain, wind, surf, or thunder), or anthropogenic noises not of interest (e.g., planes, trains, and automobiles). After extracting signals from the raw recordings, Kaleidoscope Pro then grouped the isolated signals into clusters, according to mathematical similarity. The result was a set of clusters of unclassified, but potentially interesting signals and the simultaneous elimination of much of the inconsequential noise recorded in the field.

Methods (continued)

Ideally, this process would result in “pure” clusters each containing a single class of signal (e.g., a cluster consisting only of Chuck-will’s-widow [*Antrostomus carolinensis*] calls). However, given the complex, overlapping, natural jumble of sounds present in the background soundscape, Kaleidoscope Pro tends to produce clusters that are more heterogeneous than would be optimally desired. This necessitates manual classification work performed by expert listeners who are familiar with the calls of anurans of the southeastern states.

A listener who was expert in identification of anuran calls then manually reviewed the first five signals in each cluster (i.e., those closest to the mathematical center of the cluster), which represented the five signals most representative of that cluster. When a signal consisted of anuran vocalizations that could be classified to the species level, the signal was labeled accordingly. However, we lumped any detections of northern cricket frog (*Acris crepitans*) and southern cricket frog (*Acris gryllus*) into the class “*Acris spp.*” because both species occur at the park and are difficult to reliably differentiate to species using only vocalizations. Once all manual signal reviews were completed, the listener reviewed all of the anuran classifications and selected one signal that was a representative example of each species. Each selected signal became the definitive record for a given species’ occurrence at a given sample location. Later, the SECN wildlife biologist reviewed each definitive record individually to confirm species identification and to perform data quality assurance steps. The electronic records of each species occurrence were later validated, and the records were elevated to accepted status by the SECN wildlife biologist.

Taxonomic Standards

Our use of taxonomic nomenclature followed the Integrated Taxonomic Information System (ITIS 2023). The National Park Service maintains the online database NPSpecies (NPS 2023), which documents the occurrence and status of species found in parks.

Data Analysis

We analyzed species richness and related characteristics, occupancy and spatial distribution, and frequency of detection of the park’s vocalizing anuran community. Our results were derived from a semi-automated evaluation of 13,068 minutes of audio from 26,136 recordings captured across 20 sample locations. We extracted a total of 16,902 potential signals from the audio recordings, out of which we manually classified 2,672 (15.8% of signals). We included in analyses only detections of anurans that were identified to the species level. We calculated metrics separately for native versus non-native species if applicable.

Species Richness and Composition

We defined species richness as the number of unique species detected at least once at the scale of interest. We began by calculating anuran species richness for the park as a whole, as the total number of unique species across all sample locations. We also calculated species richness at each sample location. We determined species richness separately for native versus non-native anuran species when non-native species were present.

Field methods for sampling species richness (e.g., point-counts or audio sampling) inherently produce incomplete counts, due to imperfect detection of cryptic species that may be present but are difficult to record during surveys. Observed species richness, therefore, is expected to be an underestimate of true species richness, though it offers utility as an index of the true diversity of a sample unit. Various methods exist to adjust incidence data to provide an estimated species richness that includes species present, but unobserved (e.g., multispecies occupancy models or non-parametric richness estimators, such as *iChao2*); but, these approaches may show strong bias in study areas where average occupancy is low (Tingley et al. 2020). We therefore report only unadjusted species richness, with the caveat that it should be interpreted as described above.

Occupancy

We calculated naïve occupancy (i.e., frequency of occurrence) as the percent of sampling locations where a species was detected in one or more reviewed recordings. We did not adjust occupancy estimates for probability of detection (i.e., detectability). Species with greater naïve occupancy were detected at more locations than those with low values.

Spatial Distribution

We mapped species incidence records in the park to provide a means of visually assessing spatial distributions of detected anurans across the park. An understanding of anuran distribution is beneficial for informed management of species and their requisite habitats. Following future park visits, trend analysis of data is planned in order to assess changes in species distribution and community makeup. This has potential to provide insights into influences on park diversity (e.g., land use change and habitat condition, climate issues, and hydrological processes).

Results

Species Richness

Observed species richness for native anurans at Ocmulgee Mounds National Historical Park in 2017 was 11 (Table 1). We did not detect any non-native anuran species. Mean $\pm$ SD observed species richness of native anurans per sample location was 2.4 ± 3.0 (range: 0–9; Figure 2, Table 2). All of the 11 anuran species we detected in 2017 were previously documented at the park (NPS 2023; Table 1).

The distributions of northern cricket frog (*Acris crepitans*) and southern cricket frog (*Acris gryllus*) overlap along the Fall Line and both are known to occur in the park (NPS 2023). The vocalizations of the two species are too similar to reliably separate using ARD recordings. We therefore lumped any cricket frog vocalizations into a single class (“*Acris spp.*”), and treated it as a single “species” in our estimates. However, we note that this may have artificially decreased our species richness estimates by one species.



Species Richness at Sampling Locations

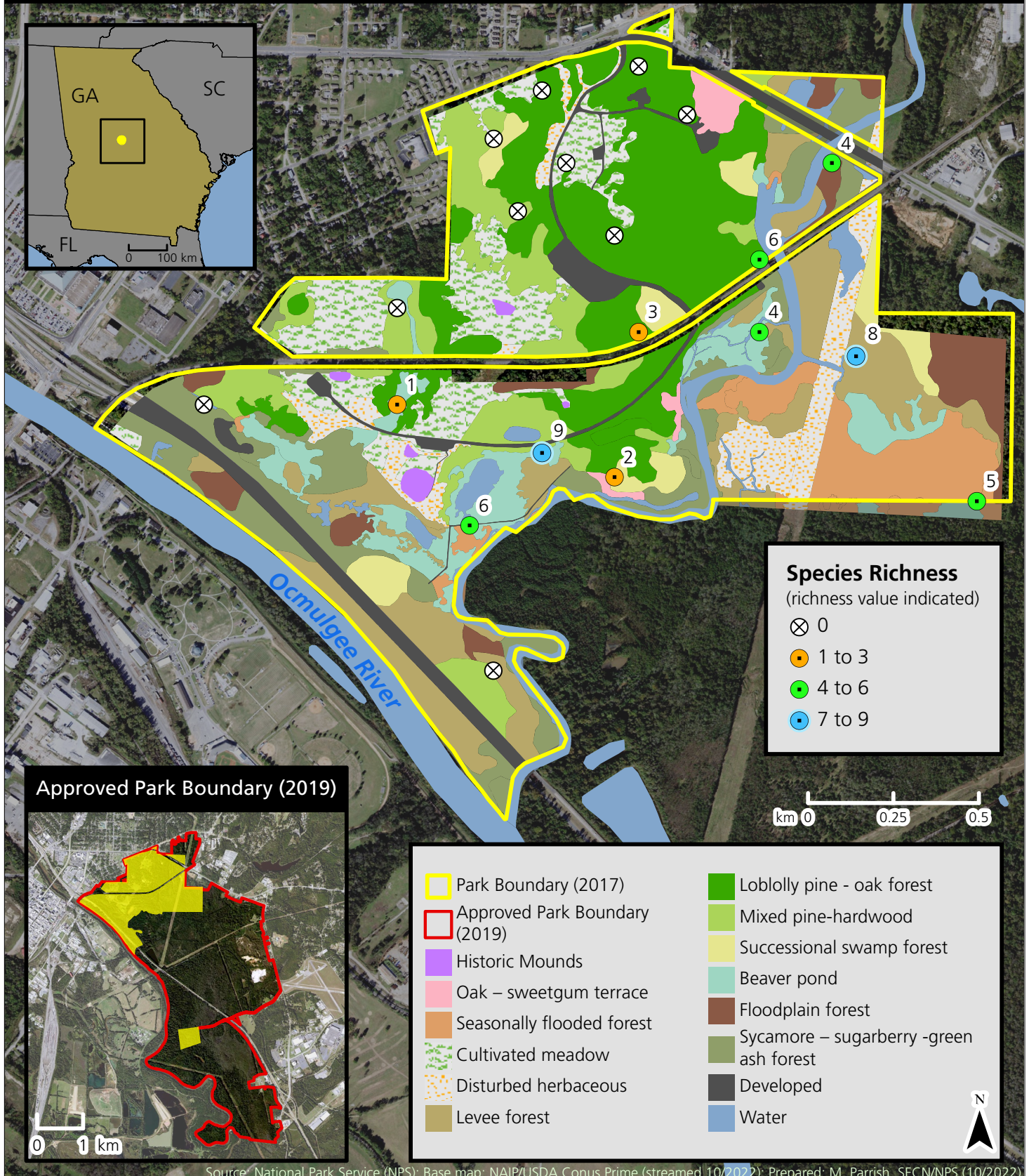


Figure 2. Vocal anuran species richness at sampling locations ($n = 20$) at Ocmulgee Mounds National Historical Park based on audio recording detections in 2017.

Table 2. Species detections (indicated with “X”) and observed species richness at each sampling location at Ocmulgee Mounds National Historical Park in 2017. Refer to Figure 1 for labeled sampling locations. “EF” = Equipment failure (no data).

Common Name	01	02	03	04	05	06	07	08	09	10	11	12	13	14	16	17	18	19	20	21	22	23
American toad	–	X	–	–	–	–	–	–	–	–	–	–	–	–	X	–	–	–	–	–	–	–
Fowler's toad	–	–	–	–	–	X	–	X	–	–	–	X	–	–	X	–	–	–	–	X	–	–
Southern toad	–	X	–	–	X	–	–	–	–	–	–	X	–	–	X	–	X	–	–	X	–	–
Cricket frog spp.	–	X	–	–	X	–	–	–	–	–	–	X	–	–	X	–	–	–	–	X	–	–
Bird-voiced treefrog	–	X	–	–	X	–	–	X	–	–	X	X	–	–	X	–	–	–	–	–	–	–
Cope's Gray treefrog	–	X	–	–	–	–	–	–	–	–	–	X	–	–	X	–	X	–	–	X	–	–
Green treefrog	X	X	–	–	X	X	–	X	–	–	–	X	–	–	X	–	X	–	–	–	–	–
Squirrel treefrog	X	–	–	–	X	–	–	X	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Spring peeper	–	X	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Eastern narrow-mouthed toad	X	X	–	–	X	–	–	–	–	–	–	–	–	–	X	–	X	–	–	–	–	–
Southern leopard frog	–	X	–	–	–	–	–	–	–	–	–	–	–	–	–	–	X	–	–	–	–	–
Observed Species Richness	3	9	0	0	6	2	EF	4	EF	0	1	6	0	0	8	0	5	0	0	4	0	0

Results (continued)

Aside from the distinctive Fowler’s toad (*Anaxyrus fowleri*), most detected toad calls were classified as southern toad (*Anaxyrus terrestris*), based on their dominant frequency at or above 2.0 kHz. Southern toad’s expected dominant frequency range (95% CI) is 1.92 to 2.08 kHz (Leary 2001). At several locations, we detected, in addition to southern toad, individual toads calling at approximately 1.8 kHz (Figure 3). The lower frequency calls fell within the high-upper frequency range of American Toad (1.65 kHz to 1.8 kHz;

Chivers 2016). The park lies along the Fall Line, which represents the contact zone between the northern range of southern toad and the southern range of American toad (Figure 4). The geographical context and somewhat intermediate calling frequency suggests some possibility that the calls were produced by hybrid *Anaxyrus americanus* X *Anaxyrus terrestris* individuals. Natural hybridization is known to occur within the *Anaxyrus americanus* species complex (Fontenot 2009), to a poorly understood extent; however, we ultimately chose to classify these observations as American toad.

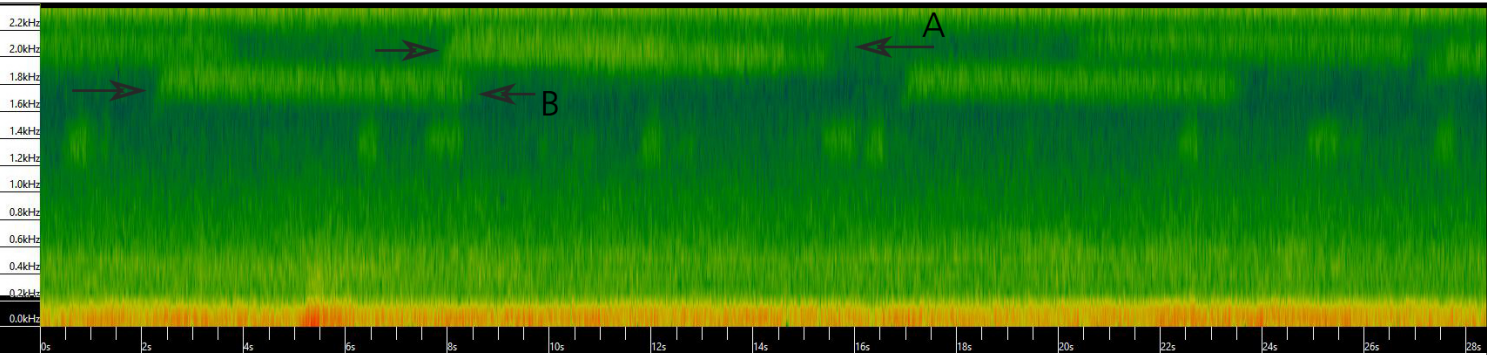


Figure 3. Frequency spectrogram depicting acoustical signatures of (A) southern toad (*Anaxyrus terrestris*) and (B) American toad (*Anaxyrus americanus*) or possible A. americanus X A. terrestris hybrid, based on audio recorded at Ocmulgee Mounds National Historical Park in 2017.

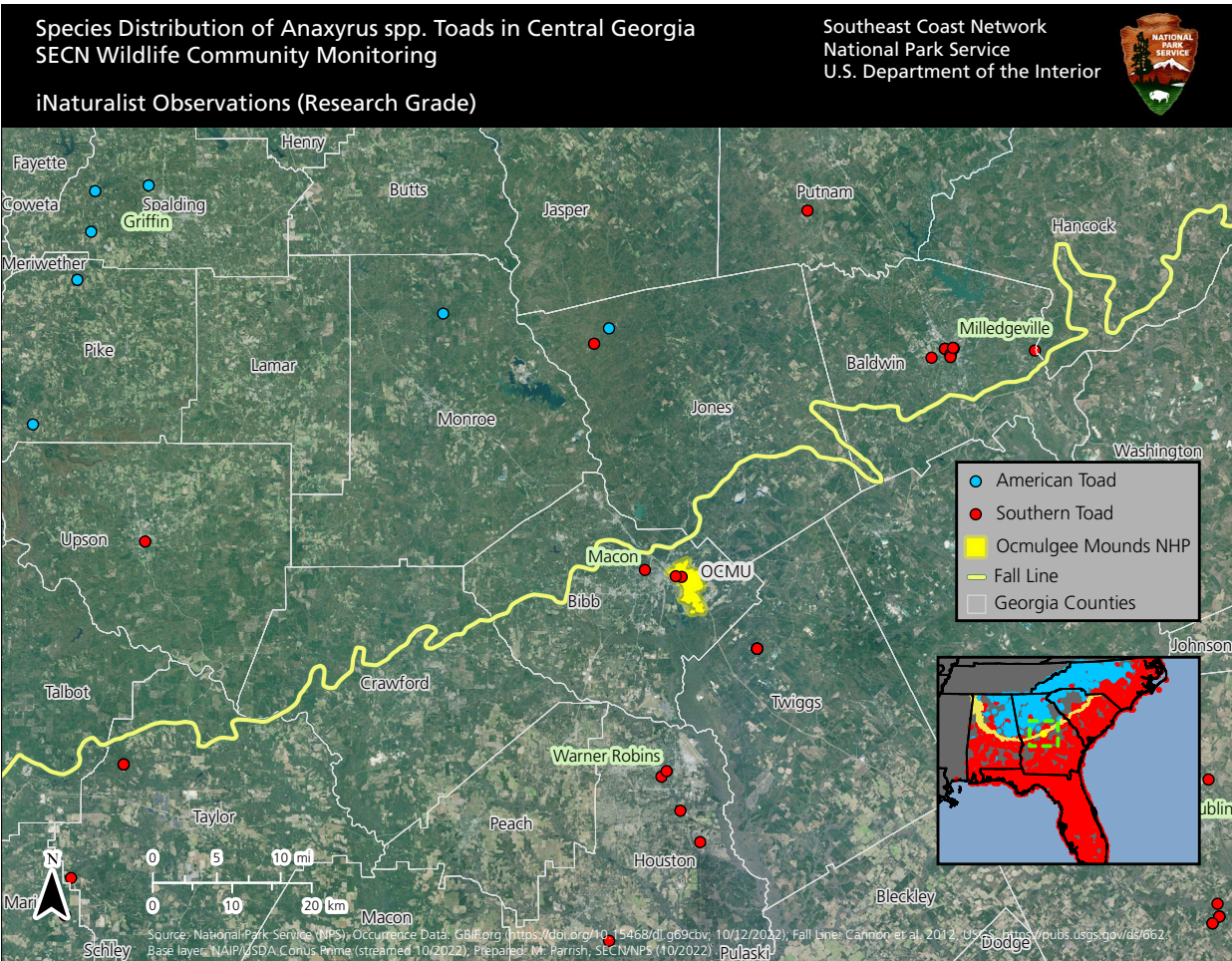


Figure 4. ‘Research-grade’ iNaturalist detections of southern toad (*Anaxyrus terrestris*) and American toad (*Anaxyrus americanus*) occurring in central Georgia, USA near Ocmulgee Mounds National Historical Park. American toad has been reported from approximately 30 kilometers (18.6 miles) north of Ocmulgee Mounds NHP.

Naïve occupancy was greatest for green treefrog (*Dryophytes cinereus*), which occurred at 40% permanent sampling locations (Table 3). Southern toad and bird-voiced treefrog (*Dryophytes avivoca*) exhibited slightly lower occupancy, and were both detected at 30% of sampled locations. American toad and southern leopard frog (*Lithobates sphenoccephalus*) were both detected at only two sample locations, and spring peeper (*Pseudacris crucifer*) was detected at only one location (Table 3).

We did not observe the following previously documented (NPS 2023) species: upland chorus frog (*Pseudacris feriarum*), southern chorus frog (*Pseudacris nigrita*), ornate chorus frog (*Pseudacris ornata*), American bullfrog (*Lithobates catesbeianus*), green frog (*Lithobates clamitans*), or eastern spadefoot (*Scaphiopus holbrookii*). Upland chorus frog calling trails off by late-March/early-April, and ARDs may not have initiated recording early enough in the spring to capture this species' vocalizations. Southern chorus frog and ornate chorus frog reach the northward edge of their coastal plain distributions in the vicinity of the park and are probably not common in the park. Advertisement calling by southern chorus frog and ornate chorus frog peaks around February, thus the species may have been missed by ARDs starting recording in April. American bullfrog and green frog are both well-within their geographic range, and both species are typically easy to detect on ARDs due to loud and frequent vocalizations. The absence of American bullfrog and green frog from recordings is perplexing. Eastern spadefoot is typically challenging to detect on ARDs, due to the species' habit of vocalizing only during short, explosive breeding periods associated with warm-weather rain events when ARDs perform poorly.

We did not detect anurans at 10 out of 20 sample locations (Figure 2). These 10 sample locations were clustered in two areas of the park: (a) along the I-16 corridor (two sample locations: 13 and 23) and (b) the section of the park north of the railroad right-of-way (locations 03, 04, 10, 14, 17, 19, 20, and 22). At an additional location proximate to the northern cluster (site 11) we detected only a single species.

Distribution maps indicating the sampling location(s) where species detections occurred are available at [Species Distribution Maps](https://irma.nps.gov/DataStore/Reference/Profile/2294565) (<https://irma.nps.gov/DataStore/Reference/Profile/2294565>) on the [NPS Integrated Resource Management Applications portal](https://irma.nps.gov/portal/) (<https://irma.nps.gov/portal/>).

We wish to thank the staff of Ocmulgee Mounds National Historical Park for assistance with sampling logistics. Wayne Ryan (intern, Cooperative Ecosystem Studies Unit / University of Georgia) assisted with data entry. Michael Byrne (SECN/NPS) was responsible for ARD field recordings in 2017. Audio classification and analyses were performed by the authors.

Common Name	Scientific Name	Naïve Occupancy ¹
Green treefrog	<i>Dryophytes cinereus</i>	40.0%
Southern toad	<i>Anaxyrus terrestris</i>	30.0%
Bird-voiced treefrog	<i>Dryophytes avivoca</i>	30.0%
Fowler's toad	<i>Anaxyrus fowleri</i>	25.0%
Cricket frog spp.	<i>Acris spp.</i>	25.0%
Cope's gray treefrog	<i>Dryophytes chrysoscelis</i>	25.0%
E. narrow-mouthed toad	<i>Gastrophryne carolinensis</i>	25.0%
Squirrel treefrog	<i>Dryophytes squirellus</i>	15.0%
American toad	<i>Anaxyrus americanus</i>	10.0%
S. leopard frog	<i>Lithobates sphenocephalus</i>	10.0%
Spring peeper	<i>Pseudacris crucifer</i>	5.0%

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About the Southeast Coast Network

In 1999, the National Park Service initiated a long-term ecological monitoring program, known as "Vital Signs Monitoring," to provide the minimum infrastructure to allow more than 270 national park system units to identify and implement long-term monitoring of their highest-priority measurements of resource condition. Monitoring resources in parks develops scientifically sound information on the current status and long-term trends in the composition, structure, and function of park ecosystems, and determines how well current management practices are sustaining those ecosystems.

The NPS Vital Signs Monitoring Program addresses five goals for all parks with significant natural resources:

- Determine the status and trends in selected indicators of the condition of park ecosystem,
- Provide early warning of abnormal conditions,
- Provide data to better understand the dynamic nature and condition of park ecosystems,
- Provide data to meet certain legal and Congressional mandates, and
- Provide a means of measuring progress towards performance goals.

The Southeast Coast Network (SECN) includes eighteen administrative areas containing twenty park units, fifteen of which contain significant and diverse natural resources. In total, SECN parks encompass more than 184,000 acres of federally-managed land across North Carolina, South Carolina, Georgia, Alabama, and Florida. The parks serve a wide diversity of cultural and natural resource missions and include: five national monuments, four national seashores, three national battlefield parks, two national historic parks, a national memorial, a national recreation area, an ecological and historic preserve, and a single national park. The parks range in size from slightly more than 20 acres to nearly 60,000 acres, and when considered with non-federal lands jointly managed with NPS, the network encompasses more than 253,000 acres.

For More Information

[SECN Home Page](https://www.nps.gov/im/secn/index.htm)

(<https://www.nps.gov/im/secn/index.htm>)

[SECN Reports and Publications](https://www.nps.gov/im/secn/reports-publications.htm)

(<https://www.nps.gov/im/secn/reports-publications.htm>)

[NPS Inventory and Monitoring Program](https://www.nps.gov/im/index.htm)

(<https://www.nps.gov/im/index.htm>)

Data Downloads via the [Natural Resource Information Portal](https://irma.nps.gov/portal/)

(<https://irma.nps.gov/portal/>)