



Vocal Anuran Community Monitoring: 2023 Data Summary

Michael C. Parrish

Southeast Coast Network, NPS, 135 Phoenix Road, Athens, Georgia 30605
<https://orcid.org/0000-0001-8475-3699>

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-indigenous species, water and air pollution, disease, and altered surface water conditions (Collins and Storer 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 2024) 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).

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



A squirrel treefrog (*Dryophytes squirellus*), one of two species detected at all locations in 2023. NPS photo (NPgallery).

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 Fort Pulaski National Monument 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).

Executive Summary

This brief summarizes data collected in 2023 at Fort Pulaski National Monument 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 February 15 to June 20 at seven spatially-balanced random sampling locations.
- We extracted 6,226 potential audio signals from 5,996 minutes of audio recordings. We manually reviewed a systematically selected subset of 1,656 (26.6%) of the extracted signals and classified to species any identifiable anuran vocalizations found in that subset.

Executive Summary (continued)

- Anurans were observed at all seven sampled locations.
- We identified three native species of anurans, each previously documented at the park. Additionally, we detected one non-indigenous anuran species, greenhouse frog (*Eleutherodactylus planirostris*).
- The frequently detected species were southern toad (*Anaxyrus terrestris*) and squirrel treefrog (*Dryophytes squirellus*), which both occurred at 100% of sampling locations (*n* = 7).
- The next scheduled sampling at this park is in 2026.

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

- [Data summary brief](https://irma.nps.gov/DataStore/Reference/Profile/2306095) (https://irma.nps.gov/DataStore/Reference/Profile/2306095)
- [Species distribution maps](https://irma.nps.gov/DataStore/Reference/Profile/2306094) (https://irma.nps.gov/DataStore/Reference/Profile/2306094)
- [Full dataset and metadata](https://irma.nps.gov/DataStore/Reference/Profile/2302261) (https://irma.nps.gov/DataStore/Reference/Profile/2302261)

Study Area

Fort Pulaski National Monument is located east of Savannah, Georgia, near the mouth of the Savannah River. The 2,276-hectare (5,623-acre) monument is comprised of two islands: Cockspur Island to the north, and McQueen’s Island to the south. Undeveloped portions of Cockspur Island are presently dominated by Eastern Red Cedar (*Juniperus virginiana*)/Live Oak (*Quercus virginiana*)/Cabbage Palmetto (*Sabal*



A southern toad (*Anaxyrus terrestris*), one of two species detected at all locations in 2023. NPS photo / Kristen Maxfield (NPgallery).

palmetto) Marsh Hammock. McQueen’s Island is less developed and is primarily in salt marsh cordgrass (*Spartina alterniflora*) cover. All SECN wildlife monitoring is conducted on Cockspur Island.

Both islands have experienced major anthropogenic alterations, since at least the 1700s. In the 1820s, construction began on Fort Pulaski on Cockspur Island and additional drainage ditches and dredge spoil deposits followed in later years. Due to the park’s location at the mouth of the Savannah River, direct and indirect effects of contaminants may affect water quality in the watershed. Ship traffic and dredging also contribute to shoreline erosion issues on the north side of Cockspur Island.

Fort Pulaski National Monument had nine previously documented anuran species when sampling occurred in 2023 (Table 1; NPS 2024).

Table 1. Anurans known to occur within Fort Pulaski National Monument based upon records in NPSpecies (NPS 2024) and those detected during our 2023 sampling. Documented species indicated with “X.”

Order	Family	Species	Authority	Common Name	NPSpecies (2024)	SECN Monitoring (2023)
Anura	Bufonidae	<i>Anaxyrus quercicus</i> ¹	Holbrook, 1840	Oak toad	–	–
		<i>Anaxyrus terrestris</i>	Bonnaterre, 1789	Southern toad	X	X
	Eleutherodactylidae	<i>Eleutherodactylus planirostris</i> ^{1, 2, 3}	Cope, 1862	Greenhouse frog	–	X
	Hylidae	<i>Acris gryllus</i>	Le Conte, 1825	Southern cricket frog	X	–
		<i>Dryophytes cinereus</i>	Schneider, 1799	Green treefrog	X	X
		<i>Dryophytes squirellus</i>	Bosc, 1800	Squirrel treefrog	X	X
		<i>Pseudacris ocularis</i>	Holbrook, 1838	Little grass frog	X	–
	Microhylidae	<i>Gastrophryne carolinensis</i>	Holbrook, 1835	Eastern narrow-mouthed toad	X	–
	Ranidae	<i>Lithobates sphenoccephalus</i>	Cope, 1886	Southern leopard Frog	X	–

¹ Recorded by SECN during 2020 monitoring (Parrish and Martin 2022).
² Recorded by SECN during 2015 monitoring (Parrish and Martin 2024).
³ Non-indigenous species; arrived in region via anthropogenic means.

Methods

Sampling Design

The Southeast Coast Network established a randomly-selected, spatially-balanced set of sample locations ($n = 7$) during an initial field season in 2015 (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 revisited on a three-year rotation. This report pertains to 2023 sampling only. 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).

Data Collection

In 2023, we deployed automated recording devices (ARDs) at seven permanent sampling locations (Figure 1) from February 15 to June 20. We programmed each ARD to record audio on every fourth night, in 60-second intervals every 20 minutes from 20:00 to 04:40, for 32 nights of sampling. Each ARD captured 855 to 857 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.



Figure 1. Permanent audio sampling locations ($n = 7$) within Fort Pulaski National Monument. Sampling location ID numbers are indicated at each point.



An automated recording device at Fort Pulaski National Monument. NPS photo / SECN staff.

Methods (continued)

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 a large proportion of the recordings do not contain signals of interest. Therefore, we began classification work by using computer program Kaleidoscope Pro (Wildlife Acoustics, Inc. 2024) to automatically review all recordings at a sample location in the park and 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 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 elimination of much of the inconsequential noise recorded in the field.

Ideally, this process would result in “pure” clusters each containing a single class of signal (e.g., a cluster consisting only of calls belonging to a single species). However, given the complex, overlapping, natural jumble of sounds present in the background soundscape, Kaleidoscope tends to produce clusters 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.

An expert listener 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. 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 2024). The National Park Service maintains the online database NPSpecies (NPS 2024), 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



A green treefrog (*Dryophytes cinereus*), one of several species detected in 2023. NPS photo (NPgallery).

vocalizing anuran community. Our results were derived from a semi-automated evaluation of 5,996 minutes of audio from recordings captured across seven sample locations. We extracted 6,226 potential signals from the audio recordings, out of which we manually classified 1,656 (26.6% of signals). We included in analyses only detections of anurans that were identified to the species level.

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-indigenous anuran species when non-indigenous 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 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 Fort Pulaski National Monument in 2023 was three (Table 1). Additionally, we detected one non-indigenous anuran species, greenhouse frog (*Eleutherodactylus planirostris*). Mean $\pm$ SD observed species richness of native anurans per sample location was 2.43 ± 0.53 (range: 2–3; Figure 2; Table 2). We detected anurans at all sampled locations.



Figure 2. Vocal anuran species richness at sampling locations within Fort Pulaski NM, based on audio recording detections in 2023.

Table 2. Species detections (indicated with “X”) and observed species richness (native-only and inclusive of non-indigenous species) at each sampling location within Fort Pulaski National Monument in 2023. Refer to Figure 1 for labeled sampling locations.

Common Name	02	04	05	06	07	08	09
Southern toad	1	1	1	1	1	1	1
Greenhouse frog ¹	0	1	0	1	1	0	1

Common Name	02	04	05	06	07	08	09
Green treefrog	0	0	0	1	1	1	0
Squirrel treefrog	1	1	1	1	1	1	1
OSR (native spp.)	2	2	2	3	3	3	2
OSR (native and introduced spp.)	2	3	2	4	4	3	3

¹ Non-indigenous species; arrived in region via anthropogenic means.
OSR = Observed Species Richness.

Results (continued)

Occupancy and Spatial Distribution

Naïve occupancy was greatest for southern toad (*Anaxyrus terrestris*) and squirrel treefrog (*Dryophytes squirellus*), which each occurred at 100% of sampling locations (Tables 2, 3). Greenhouse frog and green treefrog (*D. cinereus*) occurred at approximately 57% and 43% of sampled locations, respectively (Tables 2, 3).

All four of the anuran species we detected in 2023 were previously documented at Fort Pulaski National Monument (NPS 2024, Table 1).

We did not observe several species previously documented in the park (Tuberville et al. 2005), including oak toad (*Anaxyrus quercicus*), little grass frog (*Pseudacris ocularis*), eastern narrow-mouthed toad (*Gastrophryne carolinensis*), and southern leopard frog (*Lithobates sphenoccephalus*). Oak toad and little grass frog are expected to have low detectability on ARDs due to their calling characteristics. The other species may not have been vocally active or detectable during recording intervals. Southern cricket frog (*Acris gryllus*) was reported secondhand more than 40 years ago (SWS 1981) and since we were unable to locate the original source of the report, we are hesitant to accept that species as occurring in the park.

Cuban treefrog (*Osteopilus septentrionalis*), a non-indigenous species, has not yet been detected in the park. The species was detected in Chatham County, Georgia in 2004 (Johnson 2007) and one actively breeding individual was recently reported on Tybee Island, Georgia in September 2023 (Shepherd 2023). Based on these documented detections near the park, Cuban tree frogs could potentially become established in Fort Pulaski National Monument in the future.

Distribution Maps

Distribution maps indicating the sampling location(s) where species detections occurred are available at [Species Distribution Maps](https://irma.nps.gov/DataStore/Reference/Profile/2306094) (<https://irma.nps.gov/DataStore/Reference/Profile/2306094>).

Table 3. Naïve occupancy estimates (i.e., proportion of permanent sampling locations where a species was detected) for vocal anurans within Fort Pulaski National Monument in 2023, ranked by descending proportion of locations occupied.

Common Name	Scientific Name	Naïve Occupancy ¹
Southern toad	<i>Anaxyrus terrestris</i>	100.0%
Squirrel treefrog	<i>Dryophytes squirellus</i>	100.0%
Greenhouse frog	<i>Eleutherodactylus planirostris</i>	57.1%
Green treefrog	<i>Dryophytes cinereus</i>	42.9%

¹ Percent of sampling locations where species was observed.



An automated recording device at Fort Pulaski National Monument. NPS photo / SECN staff.

Acknowledgements

We wish to thank Jessie Jordan (Chief Ranger, Fort Pulaski NM) and Candice Smith (Biological Science Technician, Fort Pulaski, NM) for assistance with sampling logistics. Wayne Ryan (intern, Cooperative Ecosystem Studies Unit/University of Georgia) assisted with data entry. Audio classification and analyses were performed by the author.

Literature Cited

Adams M. J., D. A. W. Miller, E. Muths, P. S. Corn, and E. H. C. Grant. 2013. Trends in Amphibian Occupancy in the United States. PLOS ONE 8(5): e64347. Available at: <https://doi.org/10.1371/journal.pone.0064347> (last accessed September 2024).

Begon, M., J. L. Harper, and C. R. Townsend. 1986. Ecology: Individuals, populations and communities. Blackwell Scientific Publications. ISBN: 0-632-01337-0.

Byrne, M. W., B. D. Smrekar, L. M. Elston, J. C. DeVivo, C. J. Wright, and E. Thompson. 2013. Protocol for monitoring vocal anuran communities in Southeast Coast Network Parks. Natural Resource Report NPS/SECN/NRR-2013/720. National Park Service, Fort Collins, Colorado. Available at: <https://irma.nps.gov/DataStore/Reference/Profile/2203687> (last accessed September 2024).

Collins, J. P. and A. Storfer. 2003. Global amphibian declines: Sorting the hypotheses. Diversity and Distributions 9:89-98. Available at: <https://doi.org/10.1046/j.1472-4642.2003.00012.x> (last accessed September 2024).

Dorcas, M. E. and J. W. Gibbons. 2008. Frogs and Toads of the Southeast. University of Georgia Press. ISBN: 978-0-8203-2922-2.

Halstead, B. J., A. M. Ray, E. Muths, E. H. C. Grant, R. Grasso, M. J. Adams, K. S. Delaney, J. Carlson, and B. R. Hossack. 2022. Looking ahead, guided by the past: The role of US national parks in amphibian research and conservation. Ecological Indicators 136: 108631. Available at: <https://doi.org/10.1016/j.ecolind.2022.108631> (last accessed September 2024).

Integrated Taxonomic Information System (ITIS). 2024. Integrated Taxonomic Information System Online Database. Available at: <http://www.itis.gov> (last accessed September 2024).

Johnson, S. A. 2007. Geographic Distribution: *Osteopilus septentrionalis* (Cuban Treefrog). Herpetological Review 38(3): 349. Available at: <https://ssarherps.org/herpetological-review-pdfs/> (last accessed September 2024).

Muths, E., M. J. Adams, E. H. C. Grant, D. Miller, P. S. Corn and L. C. Ball. 2012. Amphibian Research and Monitoring Initiative Fact Sheet 2012-3092. United States Geological Survey. Available at: <https://pubs.usgs.gov/fs/2012/3092/pdf/fs20123092.pdf> (last accessed September 2024).

Literature Cited (continued)

- National Park Service (NPS). 2024. NPSpecies: Information on species in national parks. Available at: <https://irma.nps.gov/NPSpecies> (last accessed September 2024).
- Parrish, M. C., and L. H. Martin. 2022. Vocal Anuran Monitoring in Southeast Coast Network Parks: 2020 Data Summary Fort Pulaski National Monument. Southeast Coast Network. Available at: <https://irma.nps.gov/DataStore/Reference/Profile/2291582> (last accessed September 2024).
- Parrish, M. C., and L. H. Martin. 2024. Vocal Anuran Monitoring in Southeast Coast Network Parks: 2015 Data Summary Fort Pulaski National Monument. Southeast Coast Network. Available at: <https://irma.nps.gov/DataStore/Reference/Profile/2294561> (last accessed September 2024).
- Shepherd, E. R. (iNaturalist.org user: emily_rose3). 2023. iNaturalist.org observation available at: <https://www.inaturalist.org/observations/183793609> (last accessed September 2024).
- Society for the Study of Amphibians and Reptiles (SSAR). 2017. Scientific and Standard English Names of Amphibians and Reptiles of North America North of Mexico, with Comments Regarding Confidence in Our Understanding. 8th ed. pp. 1–102. Crother, B. I. (ed.). SSAR Herpetological Circular 43. Available at: <https://ssarherps.org/publications/north-american-checklist/> (last accessed September 2024).
- Southeastern Wildlife Services, Inc. (SWS). 1981. A survey of the vertebrate and invertebrate fauna of Fort Pulaski National Military Park. A report to the National Park Services. Atlanta, Georgia, Southeastern Wildlife Services, Inc.: 109 pp. Available at: <https://irma.nps.gov/DataStore/Reference/Profile/123475> (last accessed September 2024).
- Tingley, M. W., C. P. Nadeau, and M. E. Sandor. 2020. Multi-species occupancy models as robust estimators of community richness. *Methods in Ecology and Evolution* 11: 633–642. Available at: <https://doi.org/10.1111/2041-210X.13378> (last accessed September 2024).
- Tuberville, T. D., J. D. Willson, M. E. Dorcas, and J. W. Gibbons. 2005. Herpetofaunal Species Richness of Southeastern National Parks. *Southeastern Naturalist* 4(3): 537–569. Available at: [https://doi.org/10.1656/1528-7092\(2005\)004\[0537:HSROSN\]2.0.CO;2](https://doi.org/10.1656/1528-7092(2005)004[0537:HSROSN]2.0.CO;2) (last accessed September 2024).
- Wildlife Acoustics, Inc. 2024. Kaleidoscope Pro 5 User Guide. Available at: <https://www.wildlifeacoustics.com/> (last accessed September 2024).
- Zampella, R. A., J. F., Bunnell, K. J. Laidig, and N. A. Procopio. 2006. Using multiple indicators to evaluate the ecological integrity of a coastal plain stream system. *Ecological Indicators* 6(4): 644–663. Available at: <https://doi.org/10.1016/j.ecolind.2005.08.027> (last accessed September 2024).

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/>)