



Vocal Anuran Community Monitoring: 2021 Data Summary

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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. These include: 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 lives, amphibians rely heavily on availability of fresh, clean water to survive and successfully reproduce. Even seemingly minor disruptions of the aquatic or terrestrial environments upon which amphibians depend can 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; Bonett et al. 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 the breeding season, anurans are relatively easy to detect and identify, compared with other amphibians. Observed changes in anuran species composition, richness, and distribution on the landscape may indicate changes in the underlying ecological condition 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). Long-term monitoring can potentially detect anuran population trends of utility in assessments of ecosystem integrity and sustainability. Given the noteworthy diversity of amphibians in the Southeast, their sensitivity to environmental



A squirrel treefrog (*Dryophytes squirellus*), one of several species detected during monitoring in 2021. NPS photo / NPGallery.

stressors, and their evident declines in recent decades, anuran communities represent a priority for SECN monitoring efforts. Our monitoring data can be used to help inform park managers as to how changing environmental conditions may be affecting park resources and natural communities.

Objectives

This report summarizes data collected at Cape Lookout National Seashore 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 report summarizes data collected in 2021 at Cape Lookout National Seashore during implementation of the Southeast Coast Network's Vocal Anuran Community Monitoring Protocol.

- Automated recording devices (ARDs) captured anuran (i.e., frog, toad, and treefrog) vocalizations from March 31 to June 16 at 25 spatially-balanced random sampling locations.

Significant Results (continued)

- We extracted 7,977 potential audio signals from 13,077 minutes of audio recordings. We manually reviewed a systematically selected subset of 1,920 (24.1%) of the extracted signals and classified to species any identifiable anuran vocalizations found within that subset.
- We identified six native species of anurans, each of which was previously documented at Cape Lookout National Seashore. No non-native anurans were detected.
- No anurans were observed at seven of 25 sampling locations.
- The most frequently detected species was Squirrel Treefrog (*Dryophytes squirellus*) which occurred at 60% of sampled locations. Oak Toad (*Anaxyrus quercicus*) was detected at only one sampled location.
- Anuran communities at this park will be resampled in 2024.

The full dataset and metadata are on the NPS Integrated Resource Management Applications Data Store at [Full Dataset and Metadata](https://irma.nps.gov/DataStore/Reference/Profile/2299433) (https://irma.nps.gov/DataStore/Reference/Profile/2299433).

Study Area

Cape Lookout National Seashore comprises the southern portion of the North Carolina Outer Banks, and preserves approximately 56 miles of mostly undeveloped barrier islands (‘banks’) between Ocracoke Inlet and Beaufort Inlet (Figure 1). The 11,430-hectare (28,243 acres) National Seashore consists of three major islands: Shackleford Banks, South Core Banks, and North Core Banks. Additionally, Portsmouth Island, located on the northern tip of North Core Banks, was largely cut off from North Core Banks by a large breach caused by Hurricane Dorian in 2019. Access to the barrier islands from the mainland is limited to boat.

The Core Banks are low-lying (mostly less than 2 meters [6 feet] above sea level), and are subject to overwash during intense storms. In the lee of the dunes are found mostly marine grasslands and wetlands of varying sizes. Closer to the sound side of the islands, shrub thickets

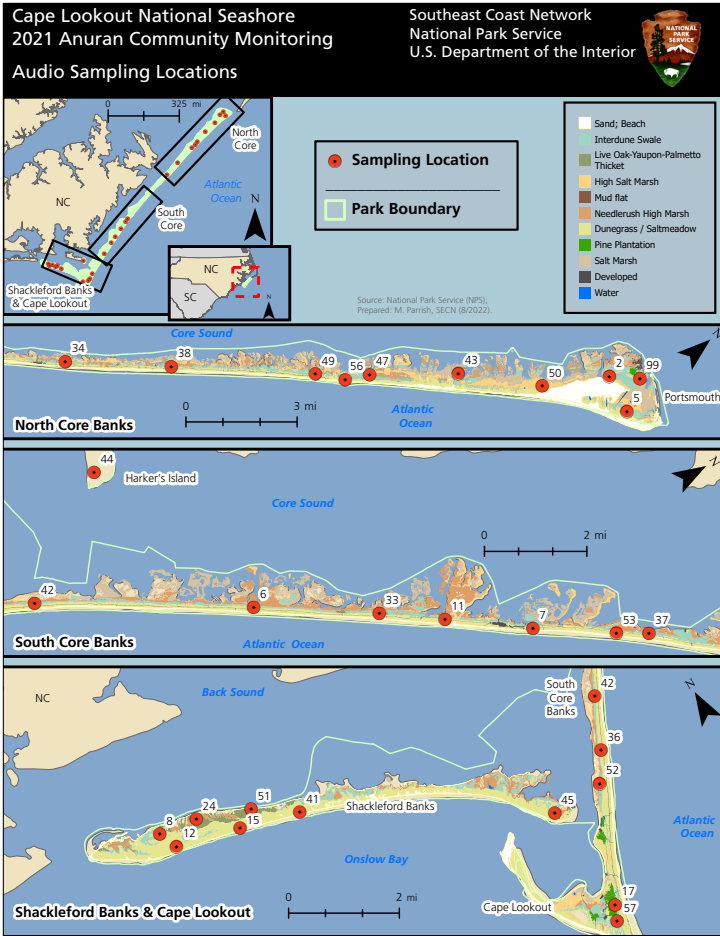


Figure 1. Permanent audio sampling locations (n = 29) at Cape Lookout National Seashore. Sampling location ID numbers are indicated at each point.

and small patches of maritime forest fringe an extensive marsh zone extending into the sound (McManamay 2017). Cape Lookout National Seashore is a very dynamic environment, with wind and water causing regular erosion and accretion across the expanse of the barrier islands. Shackleford Banks also has additional grazing pressure from over 100 non-native horses present on the island.

Cape Lookout National Seashore had eight previously-documented anuran species when sampling occurred in 2021 (Table 1; NPS 2023).

Table 1. Anurans known to occur at Cape Lookout National Seashore based upon records in NPSpecies (NPS 2023) and those detected during our 2021 sampling. Documented species indicated with “X.”

Order	Family	Species	Authority	Common Name	NPSpecies (2023)	SECN Monitoring (2021)
Anura	Bufonidae	<i>Anaxyrus fowleri</i>	Hinckley 1882	Fowler’s toad	X	X
		<i>Anaxyrus quercicus</i>	Holbrook 1840	Oak toad	X	X
	Hylidae	<i>Dryophytes cinereus</i>	Schneider 1799	Green treefrog	X	X
		<i>Dryophytes squirellus</i>	Daudin 1800	Squirrel treefrog	X	X
		<i>Pseudacris ocularis</i>	Bosc and Daudin 1801	Little grass frog	X	—
	Microhylidae	<i>Gastrophryne carolinensis</i>	Holbrook 1835	Eastern narrow-mouthed toad	X	X
	Ranidae	<i>Lithobates sphenoccephalus</i>	Cope 1886	Southern leopard frog	X	X
	Scaphiopodidae	<i>Scaphiopus holbrookii</i>	Harlan 1835	Eastern spadefoot	X	—

Methods

Sampling Design

We established a randomly-selected, spatially-balanced set of sample locations ($n = 29$) during an initial field season in 2012 (Figure 1). Our sample size was chosen based on considerations including park size, hypothesized variability in wildlife populations, and logistics. Sample locations are permanent and are revisited on a three-year rotation. This report pertains to 2021 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 2021, we deployed automated recording devices (ARDs) at 29 permanent sampling locations (Figure 1) from March 31 to June 16. Four units subsequently experienced failure in the field due to environmental damage or unknown causes, reducing our final sample size to $n = 25$. 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 20 nights of sampling. Four ARDs recorded only 17 nights due to logistical complications in deployment. The ARDs captured between 479 and 536 minutes of recordings (mean: 523 minutes). 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.

Ideally, this process would result in “pure” clusters each containing a single class of signal (e.g., a cluster consisting only of Cuban treefrog [*Osteopilus septentrionalis*] vocalizations, or a cluster containing only Chuck-will’s-widow [*Antrastomus carolinensis*] bird calls). However, given the complex, overlapping, natural jumble of sounds present in the background soundscape, Kaleidoscope tends to produce clusters that are more heterogeneous than would be optimally desired. This



An eastern narrow-mouthed toad (*Gastrophryne carolinensis*), one of several species detected during monitoring in 2021. Photo by Brad Glorioso, USGS (NPGallery).

necessitates manual classification work performed by expert listeners who are familiar with the calls of anurans of the southeastern states.

An expert in the 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 representative 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 13,077 minutes of audio captured across 25 sample locations. We extracted 7,977 potential signals from the audio recordings, then manually classified 1,920 (24.1% of signals). We included in analyses only detections of anurans that were identified to the species level. We calculated metrics separately for native vs. 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.

Methods (continued)

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 Cape Lookout National Seashore in 2021 was six (Table 1). We did not detect any non-native anuran species. Overall observed species richness was greatest on Shackleford Banks (five species) and South Core Banks (four species), and lowest on North Core Banks and Portsmouth (three species). Mean $\pm$ SD observed species richness of native anurans per sample location was 1.5 ± 1.45 (range: 0–5; Table 2; Figure 2). We did not detect any anurans at seven sample locations (006, 007, 011, 015, 043, 052, and 053).

Occupancy and Spatial Distribution

Naïve occupancy in Cape Lookout National Seashore was greatest overall for squirrel treefrog (*Dryophytes squirellus*), which occurred at 60% of permanent sampling locations (Tables 2, 3). Fowler's toad (*Anaxyrus fowleri*) and green treefrog (*Dryophytes cinereus*) occurred at approximately one third of sample locations (Tables 2, 3). Eastern narrow-mouthed toad (*Gastrophryne carolinensis*), southern leopard

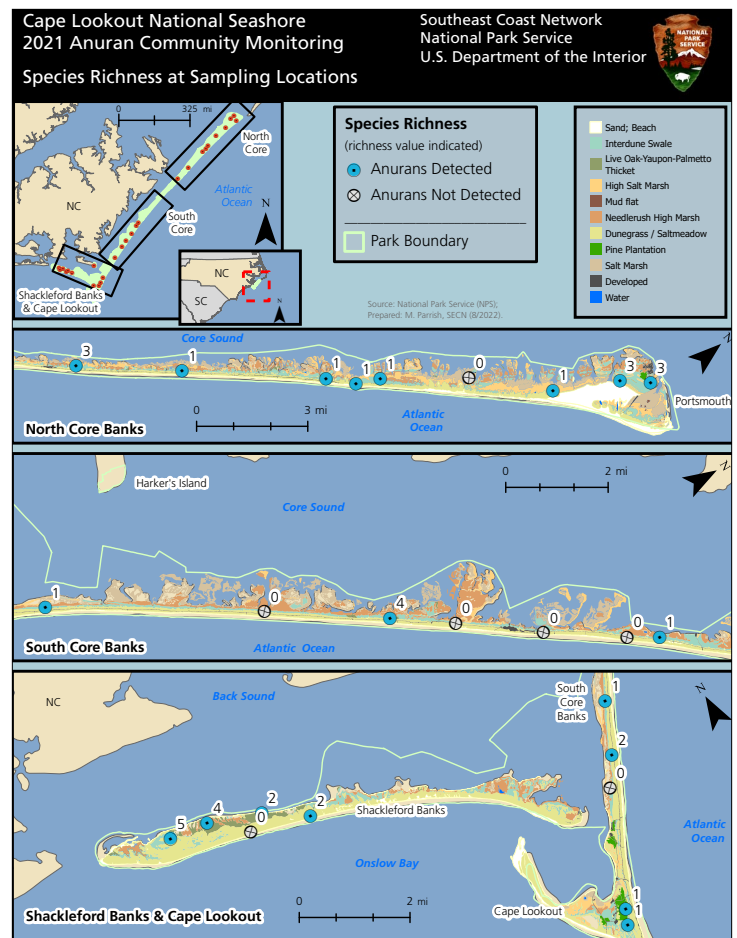


Figure 2. Vocal anuran species richness at sampling locations ($n = 25$) at Cape Lookout National Seashore based on audio recording detections in 2021. Richness values indicated at each point.

frog (*Lithobates sphenoccephalus*) and oak toad (*Anaxyrus quercicus*) were least frequently detected, and were each observed at less than or equal to three sampling locations (Tables 2, 3). Fowler's toad and squirrel treefrog were detected at all four major units at the Seashore: Shackleford Banks, South Core Banks, North Core Banks, and Portsmouth. Green treefrog was detected at Shackleford Banks, South Core Banks, and Portsmouth, but was not detected at North Core Banks. Eastern narrow-mouthed toad was detected only at Shackleford Banks and South Core Banks. Southern leopard frog was only detected at Shackleford Banks and oak toad was only detected at one location on North Core Banks. The ARD deployed at the Harkers Island site near the Visitor's Center failed.

Each of the six anuran species we detected in 2021 were previously documented at Cape Lookout National Seashore (NPS 2023, Table 1).

We did not observe little grass frog (*Pseudacris ocularis*) or eastern spadefoot (*Scaphiopus holbrookii*), which were previously documented at Cape Lookout National Seashore (Tuberville et al. 2005; NPS 2023). Little grass frog presents expected challenges to ARD detection due to its high-frequency, low-amplitude call. Eastern spadefoot calls sporadically in response to weather events, and may not vocalize during ARD recording intervals.

Table 2. Species detections (indicated with “X”) and species richness at each sampling location at Cape Lookout National Seashore in 2021. Refer to Figure 1 for labeled sampling locations.

Common Name	08 ^{SB}	15 ^{SB}	24 ^{SB}	41 ^{SB}	51 ^{SB}	06 ^{SC}	07 ^{SC}	11 ^{SC}	17 ^{SC}	33 ^{SC}	36 ^{SC}	37 ^{SC}	42 ^{SC}	52 ^{SC}	53 ^{SC}	57 ^{SC}	34 ^{NC}	38 ^{NC}	43 ^{NC}	47 ^{NC}	49 ^{NC}	50 ^{NC}	56 ^{NC}	02 ^P	99 ^P
Fowler’s toad	X	–	–	X	–	–	–	–	–	X	X	–	–	–	–	–	X	–	–	–	–	X	X	X	X
Oak toad	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	X	–	–	–	–	–	–	–	–
Green treefrog	X	–	X	–	X	–	–	–	–	X	–	X	–	–	–	–	–	–	–	–	–	–	–	X	X
Squirrel treefrog	X	–	X	X	X	–	–	–	X	X	X	–	X	–	–	X	X	X	–	X	X	–	–	X	X
Eastern narrow-mouthed toad	X	–	X	–	–	–	–	–	–	X	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Southern leopard frog	X	–	X	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Observed Species Richness	5	0	4	2	2	0	0	0	1	4	2	1	1	0	0	1	3	1	0	1	1	1	1	3	3

^{SB} Shackleford Banks

^{SC} South Core Banks

^{NC} North Core Banks

^P Portsmouth

Table 3. Naïve occupancy estimates (i.e., proportion of permanent sampling locations [$n = 25$] where a species was detected) for vocal anurans at Cape Lookout National Seashore in 2021, ranked by descending proportion of sampling locations occupied.

Common Name	Scientific Name	Naïve Occupancy ¹
Squirrel treefrog	<i>Dryophytes squirellus</i>	60.0%
Fowler's toad	<i>Anaxyrus fowleri</i>	36.0%
Green treefrog	<i>Dryophytes cinereus</i>	28.0%
Eastern narrow-mouthed toad	<i>Gastrophryne carolinensis</i>	12.0%
Southern leopard frog	<i>Lithobates sphenoccephalus</i>	8.0%
Oak toad	<i>Anaxyrus quercicus</i>	4.0%

¹Percent of sampling location where species observed

Results (continued)

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/2291584) (<https://irma.nps.gov/DataStore/Reference/Profile/2291584>) on the [NPS Integrated Resource Management Applications portal](https://irma.nps.gov/portal/) (<https://irma.nps.gov/portal/>).

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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.



An oak toad (*Anaxyrus quercicus*), one of several species detected during monitoring in 2021. NPS photo / NPgallery.



A green treefrog (*Dryophytes cinereus*), one of several species detected during monitoring in 2021. NPS photo / NPgallery.

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/>)



A Fowler's toad (*Anaxyrus fowleri*), one of several species detected during monitoring in 2021. NPS photo / NPgallery.