



Vocal Anuran Community Monitoring: 2020 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). Amphibians are particularly susceptible to perturbations of their environmental conditions, in part, because of their complex life cycles which generally include an aquatic larval stage followed by an adult terrestrial phase. Throughout their lives, amphibians rely heavily on availability of fresh, clean water to survive and successfully reproduce. Even seemingly minor alterations to 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; SSAR 2017). Thirty-two species of anurans have been documented (NPS 2022) 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 therefore 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 trends in anuran populations of utility in assessments of ecosystem integrity and sustainability. 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



A southern leopard frog (*Lithobates sphenoccephalus*), one of several species detected during monitoring in 2020. NPS photo / NPgallery.

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 Hatteras 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 during implementation of the Southeast Coast Network's Vocal Anuran Community Monitoring Protocol at Cape Hatteras National Seashore in 2020.

- Automated recording devices (ARDs) captured anuran (frogs, toads, and treefrogs) vocalizations at 14 spatially-balanced random sampling locations from March 21 to May 29.

Significant Results (continued)

- We extracted 2,471 potential audio signals from 7,290 minutes of audio recordings. We manually reviewed a systematically selected subset of 627 (25.4%) of the extracted signals and classified to species any identifiable anuran vocalizations found within that subset.
- Four native species of anurans, each previously documented at Cape Hatteras National Seashore, were identified. No non-native anurans were detected.
- No anurans were observed at five of 14 sampling locations.
- The most frequently detected species were southern leopard frog (*Lithobates sphenoccephalus*) and green treefrog (*Dryophytes cinereus*), which occurred at approximately 50% and 43% of permanent sampling locations, respectively ($n = 14$).
- Anuran communities at Cape Hatteras National Seashore are scheduled to be resampled in 2023.

The full dataset and metadata are available from the NPS Integrated Resource Management Applications Data Store at <https://irma.nps.gov/DataStore/Reference/Profile/2291585>.

Study Area

Cape Hatteras National Seashore (Figure 1) is in the northern portion of the Outer Banks, a chain of barrier islands separating the Atlantic Ocean from mainland North Carolina. Pamlico Sound, located north and west of the Outer Banks, lies between the islands and the mainland. The 9,903-hectare (24,470 acres) park extends approximately 125 kilometers (78 miles), including substantial areas on Bodie Island, Hatteras Island, and Ocracoke Island. The northern end of Bodie Island contains Pea Island National Wildlife Refuge, which is within the administrative boundaries of Cape Hatteras National Seashore, but is managed by the U.S. Fish and Wildlife Service.

As a consequence of the exposed geographical location of the islands, Cape Hatteras National Seashore is subject to intense effects from tides, storms, wind, and waves. Constantly shifting sand bars and severe weather create significant hazards to marine navigation, leading to the area's famous nickname, "Graveyard of the Atlantic." Coastal erosion, accretion, and sea overwash is an ongoing concern in the dynamic barrier island environment and dune construction has been undertaken to combat losses to the sea. North Carolina Highway 12 extends the length of Cape Hatteras National Seashore, and requires ongoing maintenance. Water management and drainage began early in the 1900s for mosquito control and to encourage waterfowl usage. The need to balance pressure from public recreational use (and associated intensive development adjacent to NPS lands) with wildlife conservation needs also represent a notable management challenge.

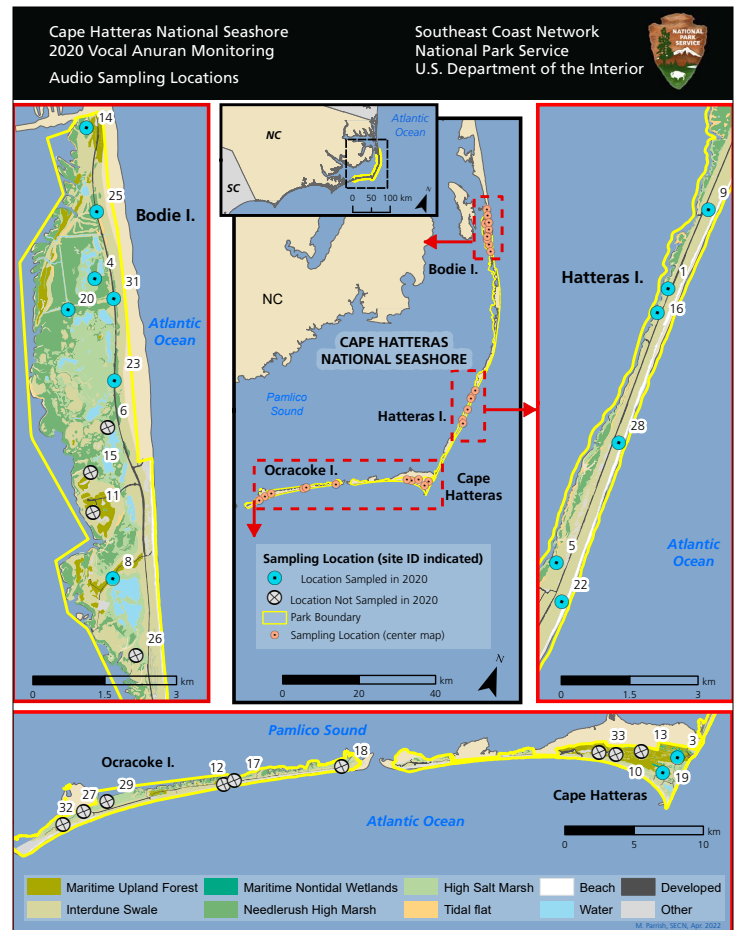


Figure 1. Permanent audio sampling locations ($n = 28$) at Cape Hatteras National Seashore. Sampling location ID numbers are indicated at each point. Thirteen sampling locations were not sampled in 2020 due to field staff recalls related to the outbreak of the COVID-19 pandemic. Sampling at location 22 was terminated due to equipment failure.

The vegetative landcover of Cape Hatteras National Seashore can be broadly classified into four dominant communities: maritime tidal wetlands, maritime nontidal wetlands, maritime open uplands, and maritime upland forests/shrublands (Boyle and Rico 2022). Surveys by the SECN terrestrial plants team in 2019 identified the following dominant plants in each community (Boyle and Rico 2022):

- Maritime tidal wetlands: saltmeadow cordgrass (*Spartina patens*), swallow-wort (*Pattalia palustre*), and marsh fimbry (*Fimbristylis castanea*);
- Maritime nontidal wetlands: common wax-myrtle (*Morella cerifera*), saltmeadow cordgrass, eastern poison ivy (*Toxicodendron radicans* var. *radicans*), and saw greenbriar (*Smilax bona-nox*);
- Maritime open uplands: sea oats (*Uniola paniculata*), dune camphorweed (*Heterotheca subaxillaris*), and seabeach evening-primrose (*Oenothera humifusa*);
- Maritime upland forests and shrublands: loblolly pine (*Pinus taeda*), southern/eastern red cedar (*Juniperus silicicola* + *virginiana*), common waxmyrtle, and live oak (*Quercus virginiana*).

Study Area (continued)

The National Park Service maintains the NPSpecies species occurrence list for Cape Hatteras National Seashore, which included 10 anuran species as of 2020 (NPS 2022). Eight of those species are reasonable to expect, based on their known range and past detections (Table 1a). The remaining two species on the NPSpecies list (American toad [*Anaxyrus americanus*] and gray treefrog [*Dryophytes versicolor*]; Table

1b) would be outside their known ranges, and we do not consider their NPSpecies records plausible. Bodie Island is near the eastern edge of the range of American toad, but we are unaware of any records of the species occurring in the park. Gray treefrog (*D. versicolor*; a.k.a. “common gray treefrog”) was historically conflated with the locally-occurring Cope’s gray treefrog (*D. chrysoscelis*), despite the former being well out of geographic range. Thus, we consider the valid species list for the park to consist only of eight species (Table 1a).

Table 1a. Anurans expected to occur at Cape Hatteras National Seashore based upon records in NPSpecies (NPS 2022) and those detected during our 2020 sampling. Documented species indicated with “x.”

Order	Family	Species	Authority	Common Name	NPSpecies (2022)	2020 Sampling
Anura	Bufonidae	<i>Anaxyrus fowleri</i>	Hinckley, 1882	Fowler’s toad	x	–
	Hylidae	<i>Dryophytes chrysoscelis</i>	Cope, 1880	Cope’s gray treefrog	x	–
		<i>Dryophytes cinereus</i>	Schneider, 1799	Green treefrog	x	x
		<i>Dryophytes squirellus</i>	Daudin, 1800	Squirrel treefrog	x	x
		<i>Pseudacris ocularis</i>	Boss and Daudin, 1801	Little grass frog	x	–
	Microhylidae	<i>Gastrophryne carolinensis</i>	Holbrook 1835	Eastern narrow-mouthed toad	x	x ¹
	Ranidae	<i>Lithobates catesbeianus</i>	Shaw, 1802	American bullfrog	x	x
		<i>Lithobates sphenoccephalus</i>	Cope, 1886	Southern leopard frog	x	x

¹ Incidental observation; included for completeness.

Table 1b. Anuran species included on the NPSpecies (NPS 2022) park list for Cape Hatteras National Seashore, which represent probable erroneous records.

Order	Family	Species	Authority	Common Name	NPSpecies (2022)	2020 Sampling
Anura	Bufonidae	<i>Anaxyrus americanus</i>	Holbrook, 1836	American toad	x	–
		<i>Dryophytes versicolor</i>	Leconte, 1825	Gray treefrog	x	–

Methods

Sampling Design

We established a randomly-selected, spatially-balanced set of sample locations ($n = 28$) during an initial field season in 2015 (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 2020 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 2020, we deployed automated recording devices (ARDs) at 15 of 28 permanent sampling locations (Figure 1) from March 21 to May 29. ARDs were not deployed at 13 sites due to COVID-19 related travel restrictions that prematurely terminated field work. One deployed ARD suffered an equipment failure in the field. Thus, in 2020, our final sample size was $n = 14$ sampling locations.

We programmed each ARD to record audio on every fourth night, in 30-second intervals every 10 minutes from 20:00 to 04:50, 18 nights of

sampling. Each ARD captured 972 recordings (486 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.



A green treefrog (*Dryophytes cinereus*), one of several species detected during monitoring in 2020. NPS photo (Npgallery).

Methods (continued)

Incidental Observations

In 2020, we captured additional recordings in June, while ARDs were awaiting retrieval. We informally reviewed these recordings and noted, for completeness, any additional species that were detected; however, the June recordings were not systematically examined according to the study methodology described above. Incidentally observed species are noted in our results with an included distribution map.

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. We began classification work by using computer program Kaleidoscope Pro (Wildlife Acoustics 2019) 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 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 [*Anurostomus 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 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. 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 Wildlife Biologist.



An eastern narrow-mouthed toad (*Gastrophryne carolinensis*), one of several species detected during monitoring in 2020. Photo by Brad Glorioso, USGS (NPgallery).

Taxonomic Standards

Our use of taxonomic nomenclature followed the Integrated Taxonomic Information System (ITIS 2022). The National Park Service maintains the online database NPSpecies (NPS 2022), 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 7,290 minutes of audio from 14,580 recordings captured across 14 sample locations. We extracted 2,471 potential signals from the audio recordings, of which we manually classified 627 (25.4% of signals). We included in analyses only detections of anurans 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 species richness at each sample location (S_{SL}). We also calculated overall species richness for the park (S_{OBS}), as the total number of unique species across all sample locations. We determined species richness separately for native vs. non-native anuran species.

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.

July 2022

Table 2a. Species detections (indicated with “x”) and native anuran species richness at each sampling location (n = 15) at Cape Hatteras National Seashore in 2020. Refer to Figure 1 for labeled sampling locations.

Common Name	01	03	04	05	08	09	14	16	19	20	23	25	28	31
Green treefrog	–	–	x	–	x	–	–	x	x	x	x	–	–	–
Squirrel treefrog	–	x	x	x	x	–	–	–	x	–	–	–	–	–
American bullfrog	–	–	–	–	–	–	–	–	x	–	–	–	–	–
Southern leopard frog	–	–	x	x	–	–	x	x	x	x	x	–	–	–
Observed Species Richness Native Species	0	1	3	2	2	0	1	2	4	2	2	0	0	0

Table 2b. Incidental species detections (indicated with “x”) at each sampling location (n = 15) at Cape Hatteras National Seashore in 2020. Refer to Figure 1 for labeled sampling locations.

Common Name	01	03	04	05	08	09	14	16	19	20	23	25	28	31
Eastern narrowmouth toad ¹	–	–	–	–	x	–	–	–	x	x	x	–	–	x

¹ Incidental observation; included for completeness.

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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,



An American bullfrog (*Lithobates catesbeianus*), one of several species detected during monitoring in 2020. NPS photo / NPgallery.



A squirrel treefrog (*Dryophytes squirellus*), one of several species detected during monitoring in 2020. NPS photo / NPgallery.

- 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>

SECN Reports & Publications:

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

About the NPS Inventory & Monitoring Program:

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