National Park Service
U.S. Department of the Interior

Natural Resource Stewardship and Science

Amphibian Community Monitoring at Cumberland Island National Seashore, 2012

Natural Resource Data Series NPS/SECN/NRDS—2013/531

ON THE COVER
Green Treefrog (*Hyla cinerea*)
Photograph by: Briana Smrekar

Amphibian Community Monitoring at Cumberland Island National Seashore, 2012

Natural Resource Data Series NPS/SECN/NRDS—2013/531

Briana D. Smrekar, Michael W. Byrne, and Lisa Kleinschmidt, and Nathan Schwartz

USDI National Park Service
Southeast Coast Inventory and Monitoring Network
Cumberland Island National Seashore
Saint Marys, Georgia 31558

August 2013

U.S. Department of the Interior
National Park Service
Natural Resource Stewardship and Science
Fort Collins, Colorado

The National Park Service, Natural Resource Stewardship and Science office in Fort Collins, Colorado, publishes a range of reports that address natural resource topics. These reports are of interest and applicability to a broad audience in the National Park Service and others in natural resource management, including scientists, conservation and environmental constituencies, and the public.

The Natural Resource Data Series is intended for the timely release of basic data sets and data summaries. Care has been taken to assure accuracy of raw data values, but a thorough analysis and interpretation of the data has not been completed. Consequently, the initial analyses of data in this report are provisional and subject to change.

All manuscripts in the series receive the appropriate level of peer review to ensure that the information is scientifically credible, technically accurate, appropriately written for the intended audience, and designed and published in a professional manner. This report received informal peer review by subject-matter experts who were not directly involved in the collection, analysis, or reporting of the data.

Views, statements, findings, conclusions, recommendations, and data in this report do not necessarily reflect views and policies of the National Park Service, U.S. Department of the Interior. Mention of trade names or commercial products does not constitute endorsement or recommendation for use by the U.S. Government.

This report is available in the Reports and Publications section of the Southeast Coast Inventory and Monitoring Network webpage (http://science.nature.nps.gov/im/units/secn/) and the Natural Resource Publications Management website (http://www.nature.nps.gov/publications/nrpm/). To receive this report in a format optimized for screen readers, please email irma@nps.gov**.**

Please cite this publication as:

Smrekar, B. D., M. W. Byrne, L. Kleinschmidt, and N. Schwartz. 2013. Amphibian community monitoring at Cumberland Island National Seashore, 2012. Natural Resource Data Series NPS/SECN/NRDS—2013/531. National Park Service, Fort Collins, Colorado.

NPS 640/121920, August 2013

Contents

Figures

Page

Figures (continued)

Page

Tables

Page

Executive Summary

The southeastern U.S. is host to one of the most diverse amphibian communities in the world. With an estimated 140 amphibian species, more than half of which are salamanders, the Southeast accounts for about half of the total number of amphibians in the U.S (Echternacht and Harris 1993, Petranka 1998). The Southeast Coast Network (SECN) has 61 known amphibian species; 26 in Caudata (salamanders, newts, amphiumas, sirens), and 35 in Anura (frogs and toads; Appendix A). Given their known population declines, sensitivity to anthropogenic stressors, and the diversity of amphibians in the southeastern U.S., amphibian communities are a priority for SECN monitoring efforts. This report summarizes amphibian community vital signs monitoring data collected at Cumberland Island National Seashore (CUIS) in 2012.

- Data were collected at 31 spatially balanced random locations using two techniques: automated recording devices (ARDs) and visual encounter surveys (VESs).

- Sampling activities occurred at the park from 2/6/2012 to 5/31/2012. Auditory recordings were collected from 2/6/2011 to 5/31/2012 and visual surveys were conducted from 2/29/2012 through 3/16/2012.

- A total of 543 vocal detections were made using the ARD recordings, where each detection represents an identifiable observation of a species or species group during one night of monitoring at a sampling location.

- We detected 10 amphibian species. We detected amphibian calls from nine identifiable species using ARDs. We detected 111 post-metamorphic amphibians in four species during VESs.

- We detected 137 reptile/reptile signs in 12 identifiable species during VESs.

- Squirrel treefrog (*Hyla squirella*) and Southern toad (*Anaxyrus terrestris*) had the highest frequency of occurrence and were the most widely-distributed amphibians at CUIS in 2012.

- Squirrel treefrog had the highest relative abundance during 2012 VESs, while the Southern toad had the highest relative detection frequency of vocalizations on the recordings.

- The Five-lined skink (*Eumeces fasciatus*) was confirmed in the park and added to the species list.

- No non-native species were found.

- Amphibian communities will next be sampled in 2016.

- The full dataset and associated metadata can be acquired from the NPS Integrated Resource Management Applications (IRMA) portal at http://irma.nps.gov.

Introduction

Overview

Amphibian populations have exhibited declines in North America and many other areas around the world. Several factors are attributable to population declines and localized extinctions. Among these factors are disease and anthropogenic stressors such as habitat loss and degradation, non-native predators, acid precipitation, altered hydrology and hydroperiod, ultraviolet radiation, and chemical contaminants (Collins and Storfer 2003). Although diseases and parasites naturally occur in amphibian populations, the effects of these influences can be exacerbated when combined with other anthropogenic stressors.

Amphibians have complex life cycles, where the immature phase often consists of an aquatic larval stage, followed by a post-metamorphic adult terrestrial stage. Slight alterations in the aquatic or terrestrial communities upon which amphibians are dependent can have substantial impacts on the survival, reproduction, and persistence of a species. Given their habitat requirements, anatomy, and physiology, amphibians are considered good indicators of ecological condition.

The southeastern U.S. is host to one of the most diverse amphibian communities in the world. With an estimated 140 amphibian species, more than half of which are salamanders, the Southeast accounts for about half of the total number of amphibians in the U.S (Echternacht and Harris 1993, Petranka 1998). The Southeast Coast Network (SECN) has 61 known amphibian species; 26 in Caudata (salamanders, newts, amphiumas, sirens), and 35 in Anura (frogs and toads; Appendix A).

Given their known population declines, sensitivity to anthropogenic stressors, and the diversity of amphibians in the southeastern U.S., amphibian communities are a priority for SECN monitoring efforts.

The National Park Service Omnibus Management Act of 1998, and other reinforcing policies and regulations, require park managers "to establish baseline information and to provide information on the long-term trends in the condition of National Park System resources" (Title II, Sec. 204). The amphibian-community monitoring data summarized herein is a tool to assist park managers in fulfilling this mandate.

This report summarizes data collected as a part of the Southeast Coast Network Vital Signs Monitoring Program's efforts to assess the status and trends of amphibian communities at Cumberland Island National Seashore (CUIS).

Study Area

Cumberland Island National Seashore (CUIS) is on the Georgia coast between St. Andrews Sound and the mouth of the St. Marys River. At 17.5 miles (28.2 km) long, CUIS is one of the largest and most diverse islands on the Atlantic Coast (Figure 1). Almost half of the Seashore's 36,415 total acres (14,737 ha) are *Spartina* spp.-dominated salt marsh community. These areas also include mud flats and six tidal creeks which provide the habitat for a diverse assemblage of marine fauna. The terrestrial areas of the park consist of Virginia live oak (*Quercus virginiana*) / cabbage palm (*Sabal palmetto*) maritime forests, extensive dune systems, interdunal wetlands, freshwater ponds and wetlands, and mixed-pine / hardwood forests in the northern part of the park. The island is known for nesting loggerhead sea turtles (*Caretta caretta*), shore birds, undeveloped dune fields, maritime forest ecosystems, and historic structures, and is host to 18 federally-listed species.

CUIS was established in 1972 to preserve the scenic, scientific, historical values of the island as well as to provide public outdoor recreational uses to its visitors. Specified areas of Cumberland Island are also part of the South Atlantic-Carolinian Biosphere Reserve and will be permanently protected in a primitive state. Approximately 4,000 ha (9,886 acres) of the northern portion of the island are designated a wilderness area. This unspoiled environment, once prevalent on all the barrier islands, provides a unique opportunity to experience the flora and fauna of a natural coastal ecosystem.

Cumberland Island National Seashore has 19 known amphibian species (NPSpecies 2013, Table A-1). The amphibians consist of 14 species in Anura (frogs and toads) and five species in Caudata (e.g. salamanders, newts, amphiumas, sirens).

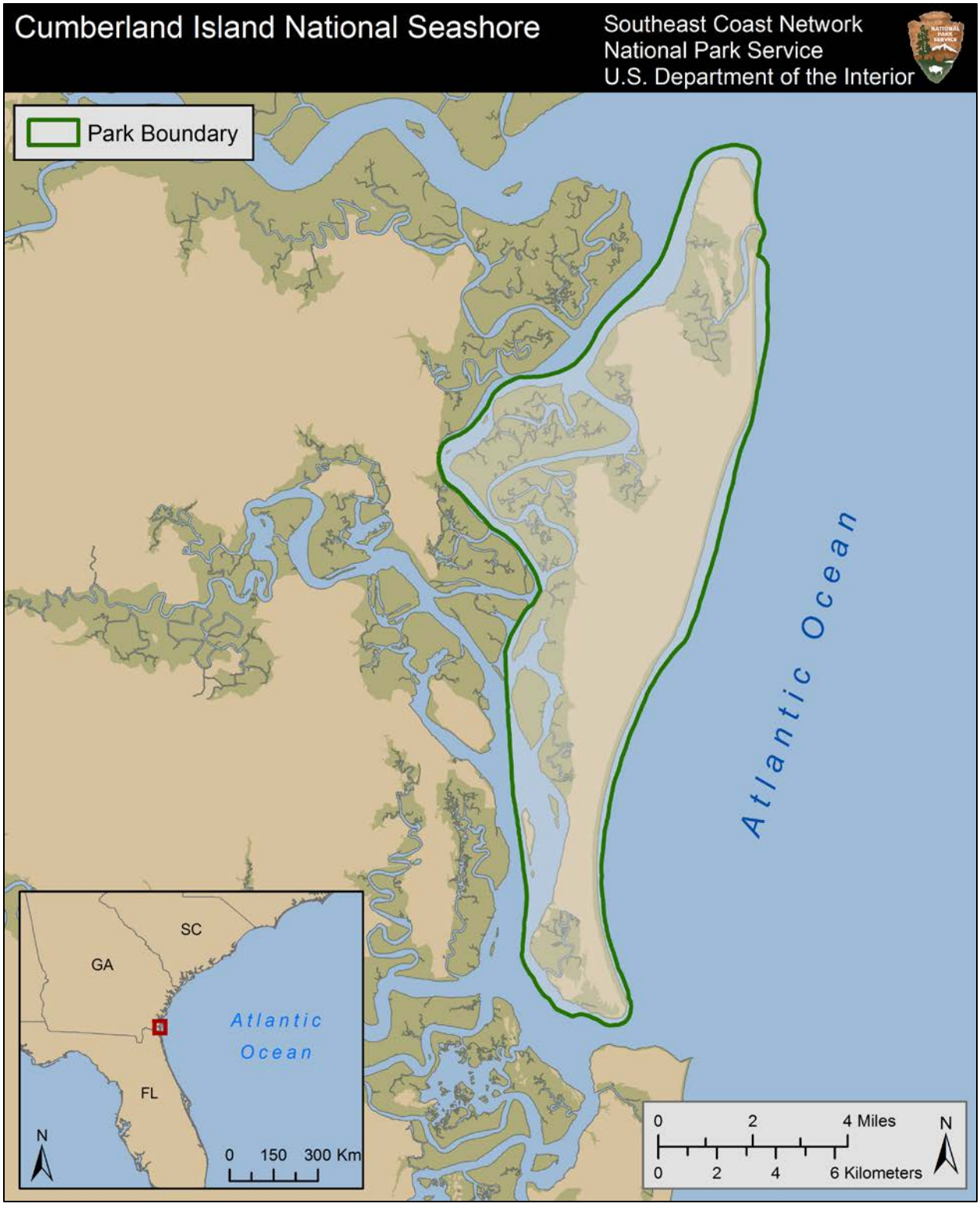


Figure 1. Location of Cumberland Island National Seashore.

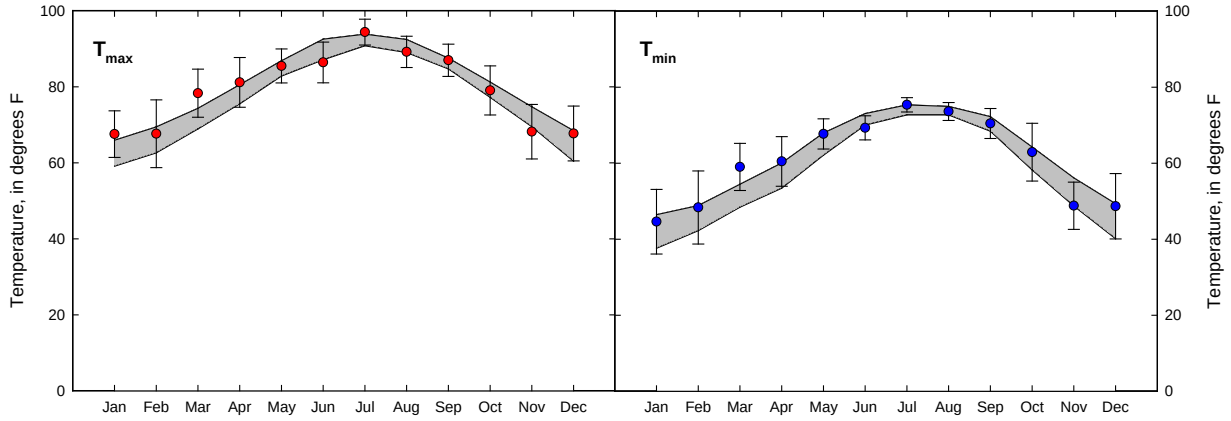
Environmental Setting During Sampling Event

Climatologically, the Southeastern U.S. experienced unusually warm average temperatures throughout the winter and spring (January to May, 2012), and near normal or slightly cooler than average summer and fall temperatures (Wright 2013). Total annual precipitation averaged below normal across the southeastern states in 2012, although Florida and Alabama experienced near normal levels. North Carolina and South Carolina had below normal precipitation, while Georgia averaged well below normal annual precipitation (Wright 2013).

Based on data collected from the Brunswick, Brunswick Malcolm McKinnon Airport, Brunswick 23 S, and the Stafford Field Cumberland Island National Seashore weather stations, mean monthly temperatures were above average during much of the SECN amphibian monitoring time frame of February through May, 2012 (Wright 2013). Average high temperatures at the Stafford Field weather station on Cumberland Island ranged from 67.3°F to 83.4°F, while average lows ranged from 47.6°F to 66.6°F during the sampling period. The weather stations in Brunswick show that during the SECN sampling timeframe, March recorded the highest departures above the long-term (30-year) average temperature (Figure 2).

Precipitation levels averaged below normal during the first part of the 2012 SECN sampling period at Cumberland Island National Seashore (February to April), but well above average during May (Figure 3). Precipitation was below average from February to April, averaging 1.64 inches of precipitation at the Stafford Field weather station. During the same time frame, stations in Brunswick recorded an average of 2.21 inches of precipitation, which is a deficit of 3.35 inches. During May, recorded precipitation was well above the 30-year average for the area, with the Brunswick area reporting 7.89 inches of precipitation above the average. Stafford Field weather station recorded 7.08 inches of precipitation in May.

A.



B.

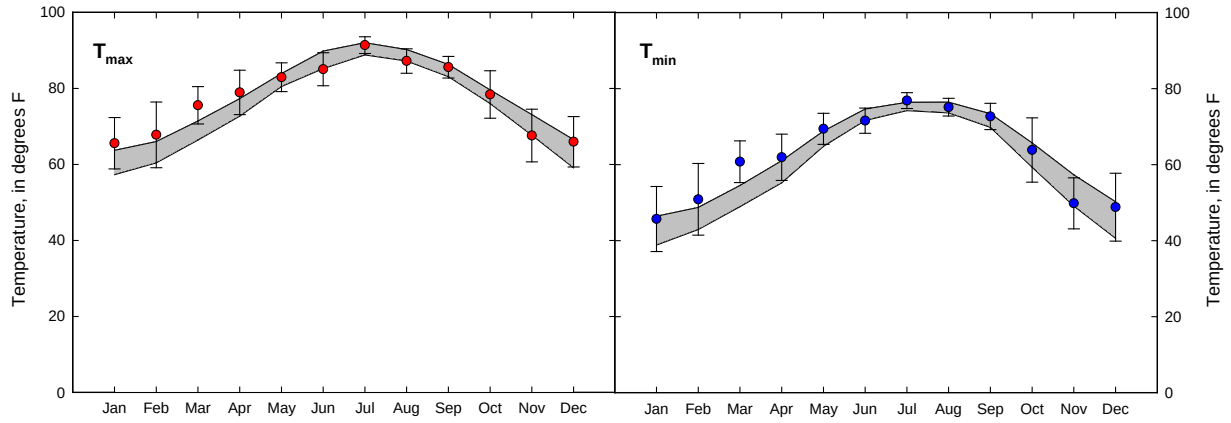
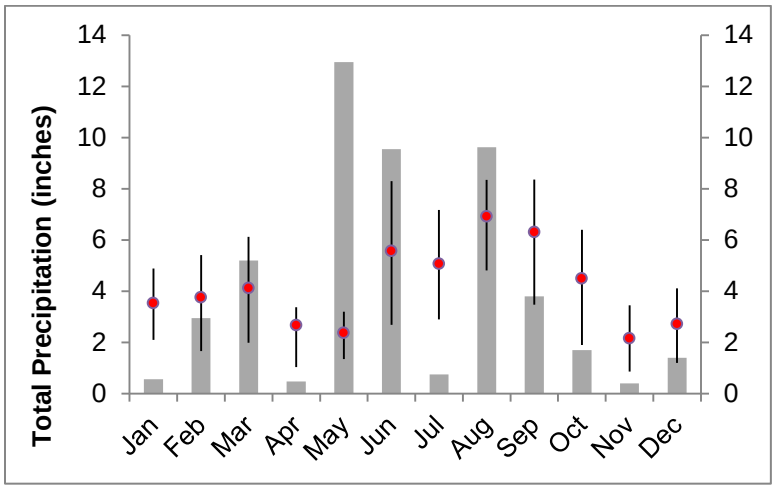


Figure 2. 2012 average monthly temperature and the 30-year (1981 – 2010) average for A. Brunswick and B. Brunswick Malcolm McKinnon Airport stations. Units = °F. Points indicate the 2012 average monthly maximum and minimum temperatures. Error bars indicate +/- standard deviation. The dual solid lines bound the standard deviation around the 30-year (1981-2010) mean monthly temperature.

A.



B.

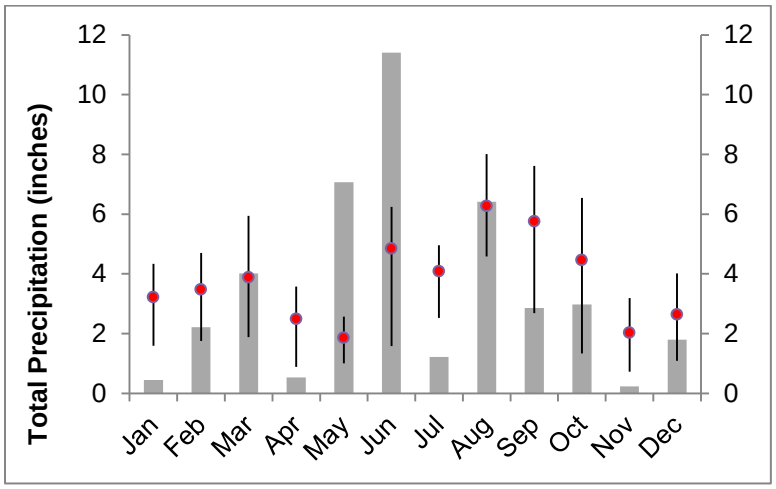


Figure 3. Total monthly precipitation during 2012 and the 30-year (1981 - 2010) monthly averages for A. Brunswick and B. Brunswick Malcolm McKinnon Airport stations. The gray columns represent 2012 total monthly precipitation. The red circles represent the 30-year average; the lines indicate the 25th and 75th percentile of the 30-year normal data for each month.

At the time when visual encounter surveys were conducted (2/29/2012 to 3/16/2012), conditions were very dry with no measureable precipitation observed and soil moisture averaging less than 1% (Table 1).

Table 1. Environmental Variables during visual encounter surveys conducted at Cumberland Island National Seashore, 2012. Averages for Noise, Precipitation, and Wind Speed are calculated as the mode of parameter codes (see footnote for code definitions).

Parameter	Average	Standard Deviation	Notes
Noise	1.00	N/A	Slight effects to sampling with barely noticeable reductions to hearing
Precipitation	0.00	N/A	No Precipitation
Relative Humidity (%)	74.62	12.42	
Soil Moisture (%)	0.89	0.99	
Temperature (ºF)	69.70	6.32	
Wind Speed	0.00	N/A	<1 mph

[1] Noise codes are determined in the field as follows: 0 – No appreciable effect, no background noise; 1 – Slightly affecting sampling, barely reduces hearing; 2 – Moderately affecting sampling, noticeable reduction of hearing; 3 – Seriously affecting sampling, noticeable reduction of hearing; 4 – Profoundly affecting sampling, greatly reduced hearing.
[2] Precipitation codes are determined in the field as follows: 0 – None; 1 – Mist or fog; 2 – Light drizzle; 3 – Light rain; 4 – Heavy rain; 5 – Sleet; 6 – Snow.
[3] Wind speed codes are determined in the field as follows: 0 – Calm (< 1mph), smoke rises vertically; 1 – Light air (1-3 mph), smoke drifts, weather vane inactive; 2 – Light breeze (4-7 mph), leaves rustle, can feel wind on face; 3 – Gentle breeze (8-12 mph), leaves and twigs move around, small flags extend; 4 – Moderate breeze (13-18 mph), moves thin branches, raises loose papers; 5 – Fresh breeze (19-24 mph), small trees begin to sway; 6 – Strong breeze (>24 mph), large branches moving, wind whistling.

Monitoring Objectives

Analysis of amphibian monitoring data is based on detections of vocal anurans using automated recording devices, where a detection is considered to be one or more observations of a species or species group during one night of monitoring at a sampling location. The SECN has four monitoring objectives related to amphibian communities based on amphibian post-metamorphic anuran vocalization data collected from March to mid-June in non-saline wetland and upland vegetation communities in all Southeast Coast Network parks (Byrne et al. 2013 *in review*):

- *Determine the status and trends in species richness and diversity of amphibian communities.* Species richness and diversity estimates are based on the total number of species detected (i.e., native and non-native).

- *Determine the status and trends in occupancy by amphibian species*. Occupancy estimates provide insight into the likelihood of encountering a specific species, rarity, diversity, and distribution of a species or group, and relative comparisons provide insight into the composition of the sample.

- *Determine the status and trends in frequency of detection of vocal anurans.* Frequency of detection is the number of nights a species or species group is observed during the sampling event at each sampling location.

- *Determine trends in the vocalization phenology of select anurans with high detectability*. Vocal anuran calling patterns of species with high detectability (i.e., an unbiased detectability estimated generated from the occupancy-modeling process) will be analyzed to determine the status and trends in the first and last dates on which species are detected.

Additional amphibian and reptile data based on visual encounter methods that were being tested as a part of protocol development in FY 2012 are also presented below.

Methods

Sampling Design

To allow for park-wide inference, the CUIS administrative boundary was used as the sampling frame, within which a spatially-balanced sample was drawn using the Reversed Randomized Quadrant-Recursive Raster (RRQRR) algorithm (Theobald et al. 2007). Alternate points were used when selection criteria (i.e., including safety and access issues) were not met. In 2012, Amphibian Communities were sampled at 30 locations that met the selection criteria (i.e., safety and access considerations) as described in Byrne et al. (2013 *in review*) (Figure 4).

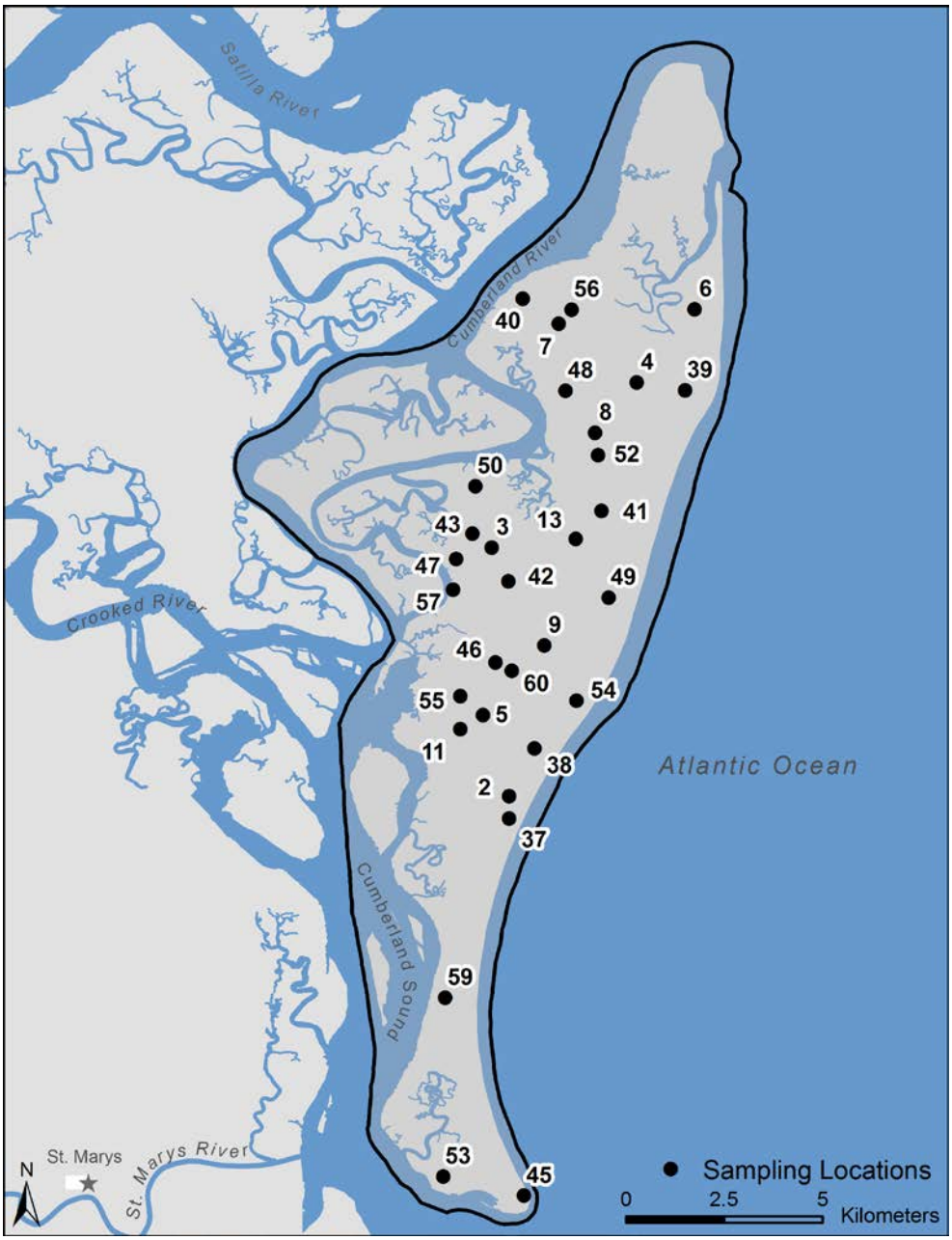


Figure 4. Spatially-balanced random sampling locations at Cumberland Island National Seashore, 2012.

Sampling Methodology

Three sampling techniques were used as part of SECN amphibian monitoring, including a combination of active and passive sampling techniques. The active techniques were a time- and area-constrained medium-intensity visual encounter survey (VES) that was conducted systematically through the 0.5-ha macroplot, and the dip-net techniques incorporated in sampling locations with aquatic communities. All species or species sign detected by sight or sound were recorded as part of the VESs. The passive technique was an automated-recording device (ARD) programmed to record every four days from 18:00 (6:00 pm) to 06:50 am for 30 seconds of every 10 minutes. Use of multiple techniques, as a "toolbox" approach (Olson et al. 1997), is generally agreed to be the most effective means to monitor amphibian communities (Hutchens and DePerno 2009). The sampling techniques were co-located, with the ARDs deployed at the center point of each 0.5-ha macroplot where VES sampling occurred (Figure 5). All three techniques adequately detect any species that occurs in the 0.5-ha macroplot.

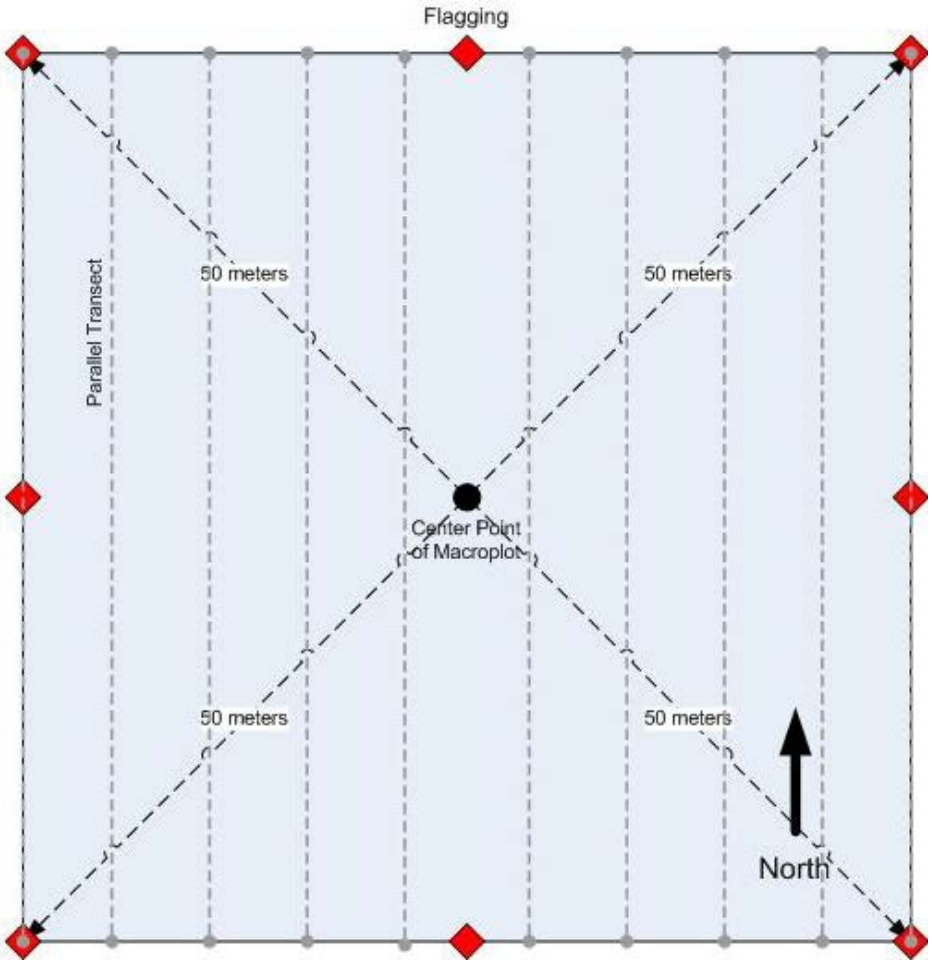


Figure 5. Macroplot (0.5-ha) layout for amphibian community monitoring in Southeast Coast Network parks. Visual encounter surveys (VESs) occur along parallel transects within the macroplot; Automated recording devices (ARDs) are deployed for 77 days at or near the center point of the macroplot.

Automated Recording Devices

Automated recording devices are often used to characterize soundscapes. Recently this technology has been applied to monitoring wildlife species. The use of ARDs is advantageous in

SECN parks because of (a) the high number of vocal anurans (i.e., vocalizing frogs and toads) in SECN parks (i.e., 35), (b) many of these species are assumed to be broadly distributed across park lands, (c) crepuscular and nocturnal calling behavior predominates the vocal anurans in SECN parks (Mohr and Dorcas 1999, Bridges and Dorcas 2000, Todd et al. 2003), (d) night-time calling surveys are a concern given the safety issues for personnel conducting the surveys, and (e) the resultant detection/non-detection data of ARDs adheres to the monitoring objective. Further, the devices produce a permanent data product (i.e., recordings) that can be further analyzed as technology improves, analyzed by other researchers, analyzed for other taxa, or to quantify the soundscape.

To address some of the known influences related to imperfect detection (MacKenzie et al. 2002, MacKenzie et al. 2006), devices are usually deployed for a duration of 77 days (20 recording sessions) to ensure detection of species present at the park as well as to assess changes in calling phenology. After the deployment period, the devices were retrieved and audio files were analyzed by SECN staff to determine the date, time, and species of all vocal anurans that were detected. Because of significant weather events in 2012, we were unable to retrieve the ARDs at 77 days. Thus, ARDs were deployed at CUIS for 113 days, and recorded for 29 sessions. We have chosen to analyze all recordings and the results from the full 29 recording sessions are included in this report.

As is the case with all data collected with ARDs, the information derived is based on species' detectability. The occupancy estimates and phenology trends are based on methodology and data collection that does not account for environmental cues that initiate calling behavior (e.g., rainfall, humidity, and temperature). Additionally, while every effort is made to ensure that our recording timeframe is sufficient to encompass most vocalizing anurans, the recordings are only a portion of the time during which anurans are active. To adequately characterize the anuran community, we determined the most appropriate timeframe for deploying the ARDs in SECN parks to be March through June based on vocalization-phenology information (Dorcas and Gibbons 2008) and data from 2009-2012 recordings in National Park units across the SECN. The most appropriate anuran candidate species' vocalization dates are published in this report.

ARDs were deployed from 2/6/2012 to 5/31/2012. A total of 33,841 minutes was recorded by all of the devices deployed at Cumberland Island National Seashore. The ARD malfunctioned or was damaged in a storm and recorded only partial data at two sampling locations (8 and 9).

Visual Encounter Surveys

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

Visual Encounter Surveys were conducted at Cumberland Island National Seashore from 2/29/2012 to 3/16/2012.

Taxonomic Standards

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

Data Analysis

This protocol collects detection / non-detection data, which, although somewhat inaccurately, is also often referred to as presence / absence data. In contrast to detections made from visual survey methods where individuals can be seen, differentiated, and counted, detections from our other surveying method, automated recording devices, cannot be reliably associated with more than one individual. In general, one individual will vocalize multiple times during the survey period and is likely to be detected multiple times. Consequently, data-summary techniques do not equate one vocalization with one individual and are conducted accordingly.

Composition

Measures of community composition are often good indicators of abiotic variability, disturbance, or other stressors. Summaries related to composition include the total number of species detected (i.e., species richness), naïve occupancy, relative abundance, and relative detection frequency. Species richness is simply the number of native species detected. Naïve occupancy is the percentage of the sampling locations where a species was detected at least once, without adjusting for probability of detection. Naïve occupancy is also referred to as frequency of occurrence. Relative abundance is the number of individuals of a particular species expressed as a percentage of the total number of amphibians in the sample. The sample size is the total number of amphibians counted at all sampling locations in the park. Relative detection frequency uses the detection history as an index of abundance to communicate the composition of each species detected relative to all other species detected in the sample. To minimize the bias inherent in this summary from the influences of detectability, vocalization behavior, sound properties, and various aspects of the automated analysis process, the estimate of relative detection frequency is derived by pooling across the detection histories and sampling locations for each species.

Distribution

Understanding changes in the distribution of amphibian species is integral to informed management of species and their requisite habitats. Changes in species distributions over time provide useful information at both the local and landscape scale relating to how species respond to large-scale influences such as changing land use, climate, hydrology, or habitat availability and condition. Shifting species distributions can produce cascading effects through altered species interactions and alterations within the food-web structure, thereby affecting ecosystem processes (Montoya and Raffaelli 2010). Distribution maps for all amphibian species encountered are presented in Appendix B.

Phenology

Phenology, the periodic life-cycle events of plants and animals as they are influenced by changes in the seasons, is an increasingly useful tool in monitoring climate change and its potential effects on amphibian populations (Blaustein et al. 2001, Gibbs and Breisch 2001, Corn 2005, Parmesan 2007, Blaustein et al. 2010, Todd et al. 2011). The timing of anuran territorial and mating vocalizations can provide insight into the initiation of the breeding season for these animals, and tracking these dates may prove to be a robust method for monitoring climate change, as it presents in the southeastern United States. The SECN reports the earliest and latest vocalization dates of select anuran species based on their known annual vocalization pattern, and the recording window of our methodology. Periodic synthesis reports, which will be published after multiple rounds of sampling, will summarize phenological history of amphibian species detected across the SECN for which appropriate candidates for trend analysis are available.

Results

Community Composition

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

We detected 10 amphibian species during sampling activities at CUIS in 2012. During the VESs, we detected 111 post-metamorphic amphibians in four species (Table A-3). No larval stage amphibians were detected, likely due to the early time of year during which the visual encounter surveys were completed. Using ARDs we detected vocalizing anurans in nine species (Table 2). Two amphibian species composed approximately 96% of the VES sample and three anuran species accounted for over 85% of the vocalizations detected, indicating low species diversity during our sampling timeframe.

Squirrel treefrog (*Hyla squirella*) and the Southern toad (*Anaxyrus terrestris*), each detected at over 90% of the sampling locations in Cumberland Island National Seashore, had the highest frequency of occurrence (naïve occupancy) of all amphibians detected during our 2012 surveying period (Table 2). Green treefrog (*Hyla cinerea*) had a 52% frequency of occurrence, followed by the pinewoods treefrog (*Hyla femoralis*) and the spring peeper (*Pseudacris crucifer*) at 42% and 23% naïve occupancy, respectively. There were no salamander species detected during 2012 sampling activities.

The Southern toad had the highest relative detection frequency of vocalizations recorded by ARDs over the 113-day sampling period, accounting for approximately 42% of all vocalizations (Figure 6). Squirrel treefrog had the second highest relative vocalization detection frequency, composing 36% of the vocalization detections. The Southern leopard frog and the pig frog (*Lithobates grylio*) had the lowest relative frequency of detection rates.

Amphibian species diversity was low during visual encounter surveys, with four species detected at CUIS in 2012. The squirrel treefrog had the highest relative abundance of amphibian species during the VESs, accounting for 63% of all amphibians counted during sampling activities (Figure 7). The green treefrog, which composed 33% of the amphibian sample counted during VESs, had the next highest relative abundance at CUIS in 2012. Just two other species were detected during the VESs, the Southern cricket frog (*Acris gryllus*) and the Southern leopard frog (*Lithobates sphenocephalus*). The Southern cricket frog was only detected during VESs, and was not recorded vocalizing on the ARDs. Despite having the highest relative detection frequency of vocalizations recorded by ARDs during the 2012 recording timeframe, the Southern toad went undetected during VESs. No non-native amphibian species were detected.

Table 2. Percentage of sampling locations where each amphibian species was detected (i.e., naïve occupancy) by method and across methods at Cumberland Island National Seashore, 2012.

	Detection Method		
Species	**All**	**VES**	**ARD**
Squirrel Treefrog	90.3	*45.2*	*80.6*
Southern Toad	90.3	*0.0*	*90.3*
Green Treefrog	51.6	*32.3*	*45.2*
Pine Woods Treefrog	41.9	*0.0*	*41.9*
Spring Peeper	22.6	*0.0*	*22.6*
Little Grass Frog	6.5	*0.0*	*6.5*
Southern Leopard Frog	6.5	*3.2*	*3.2*
Pig Frog	6.5	*0.0*	*6.5*
Eastern Narrow-mouthed Toad	6.5	*0.0*	*6.5*
Southern Cricket Frog	6.5	*6.5*	*0.0*
Total Sampling Locations	**31**	***31***	***31***

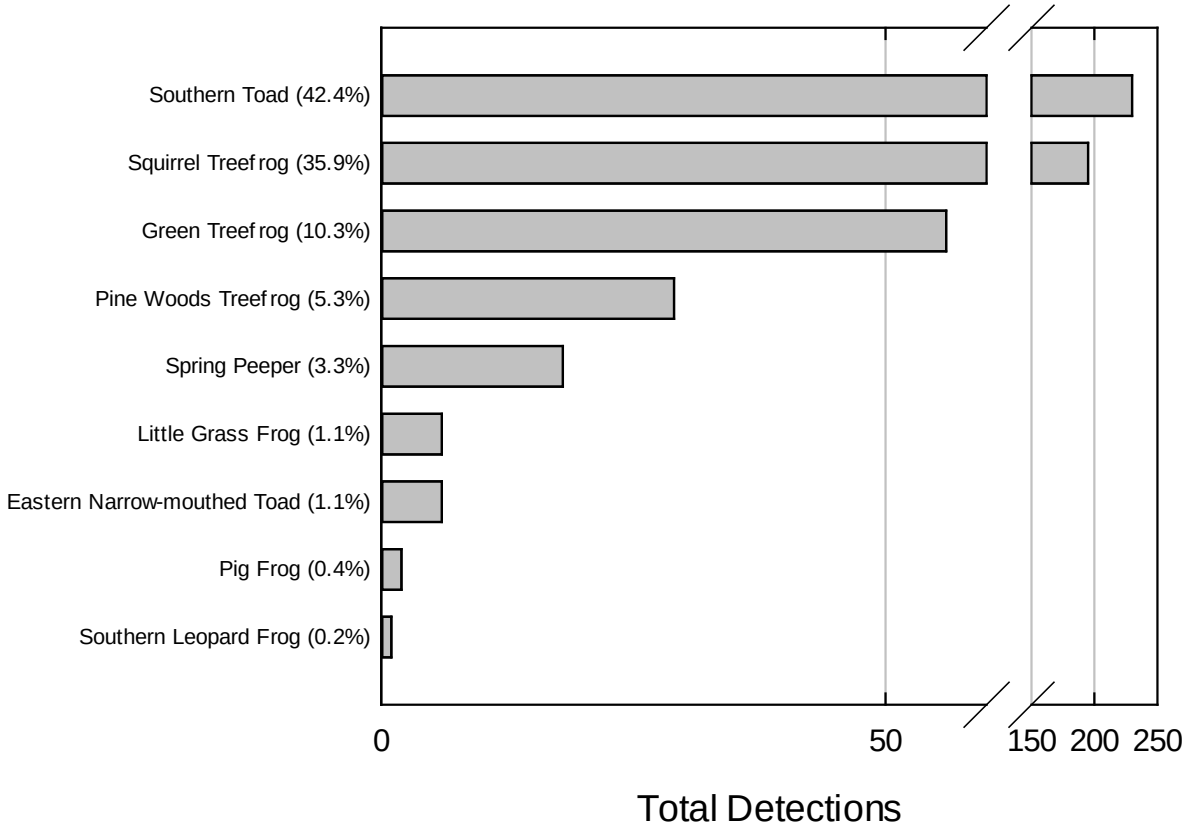


Figure 6. Number of anuran vocalization detections and the percent relative detection frequency (i.e., number of species vocalizations compared to all species' vocalizations) of recorded calls during automated recording device (ARD) deployment (2 February to 31 May 2012) at Cumberland Island National Seashore. Based on n=543 detections.

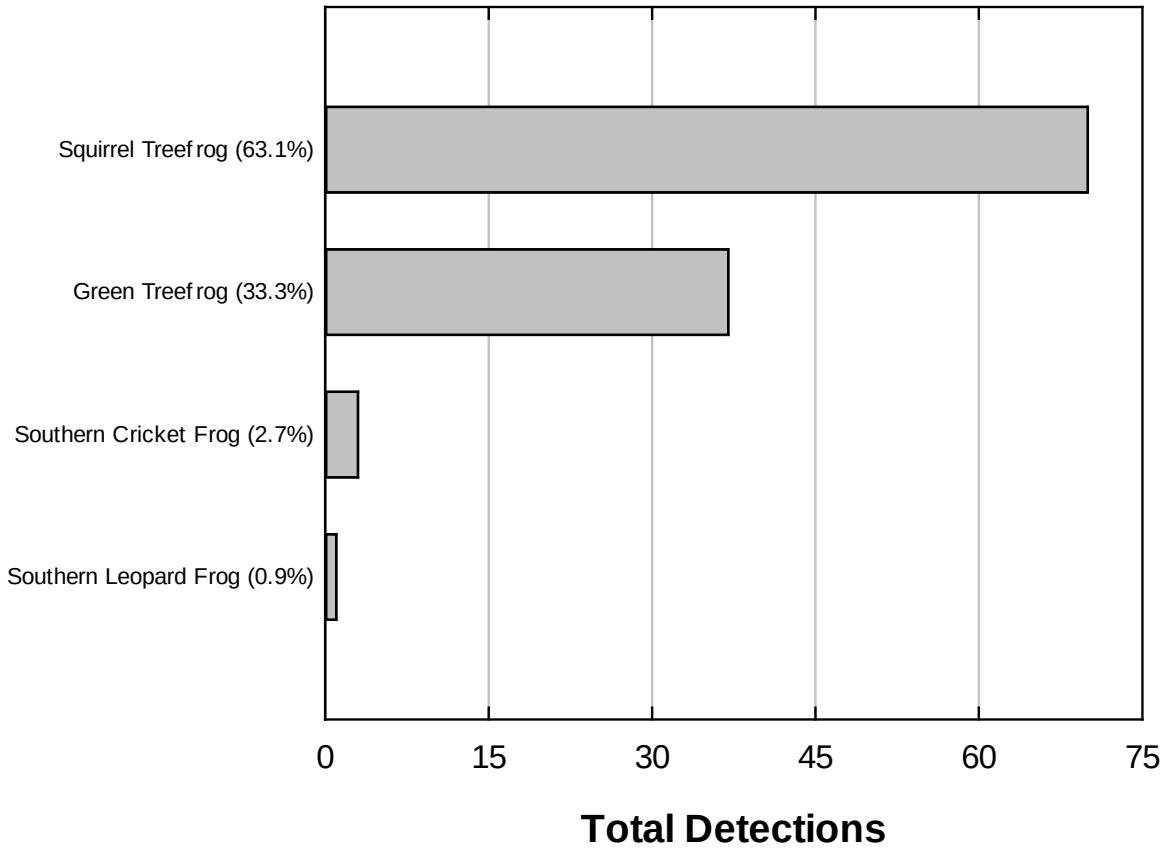


Figure 7. Number of individual amphibians detected and the relative abundance (as a percentage) of each species in the sample of post-metamorphic amphibians detected during visual encounter surveys at Cumberland Island National Seashore, 2012. Based on n=111 detections.

New Species Records

All amphibian species detected during the monitoring event were previously known to occur at Cumberland Island National Seashore.

Amphibian Distribution

The southern toad and the squirrel treefrog were the most widely distributed amphibian species at CUIS in 2012, and both were found at sampling locations throughout the park (Table 2, Appendix B). The green treefrog was also distributed throughout the north-south expanse of the park, although at fewer sampling locations. The narrowest distributions were found for the Southern cricket frog, little grass frog (*Pseudacris ocularis*), Eastern narrow-mouth toad (*Gastrophryne carolinensis*), pig frog and Southern leopard frog. Of special interest was the apparently seasonal amphibian diversity found at CUIS sampling location 46. We were unable to detect any amphibians at this sampling location, located in a tidally influenced marsh dominated by Sand Cordgrass (*Spartina bakeri*), and water salinity was high at the time of VESs in March, 2012. However, in April and May 2012, we detected eight species vocalizing at this location via ARDs. This location evidently experiences high seasonal variability in water

salinity levels, enabling it to serve as a breeding location for amphibians. Distribution maps for all amphibians that were detected during the monitoring event are presented in Appendix B.

Vocalization Phenology

Of the anurans detected at Cumberland Island National Seashore using ARDs in 2012, four species would be appropriate candidates to determine trends in vocalization start dates, squirrel treefrog, green treefrog, pinewoods treefrog, and Eastern narrow-mouthed toad. These species were considered appropriate candidates because they typically begin to vocalize well after the start of our recording schedule in the SECN parks (Dorcas and Gibbons, 2008). The first vocal detection of the squirrel treefrog occurred on 3/2/2012. The green treefrog was first detected on 3/15/2012, while the pinewoods treefrog initiated calling on 4/24/2012. The earliest vocal detection of the eastern narrow-mouthed toad was on 5/21/2012. One species is an appropriate candidate for tracking end dates due to the timing of its typical vocalization window in the Southeast, which closes well before our recording schedule concludes. The spring peeper was last detected using ARDs on 3/15/2012 (Figure 8).

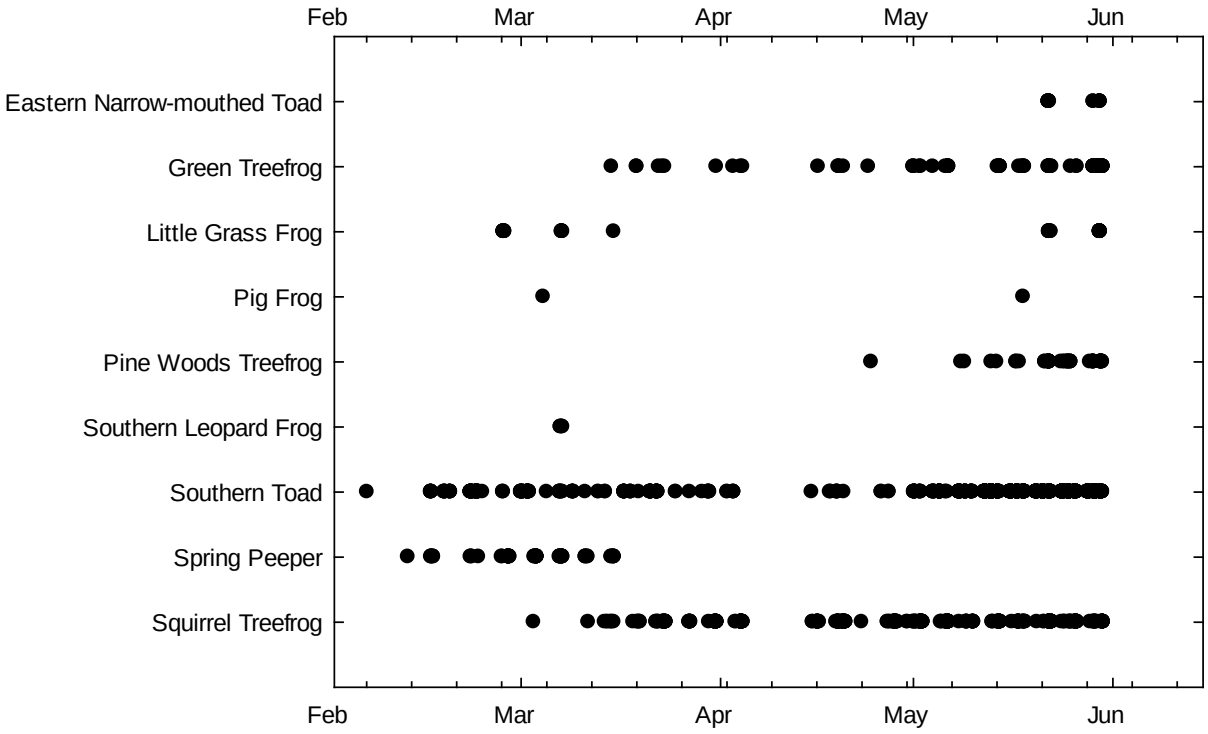


Figure 8. Vocalization phenology for species detected using automated recording devices (ARDs) at Cumberland Island National Seashore, from 2 February to 31 May 2012. Based on n=543 detections

Literature Cited

Blaustein, A. R., L. K. Beldon, D. H. Olson, D. M. Green, T. L. Root, and J. M. Kiesecker. 2001. Amphibian breeding and climate change. Conservation Biology 15:1804-1809.

Blaustein, A. R., S. C. Walls, B. A. Bancroft, J. L. Lawler, C. L. Searle, and S. S. Gervasi. 2010. Direct and indirect effects of climate change on amphibian populations. Diversity 2:281-313.

Bridges, A. S., and M. E. Dorcas. 2000. Temporal variation in anuran calling behavior: implications for surveys and monitoring programs. Copeia 2:587-592.

Byrne, M. W., J. C. DeVivo, B. D. Smrekar, L. M. Elston, C. J. Wright, and E. Thompson. 2013. *In review*. Protocol for monitoring vocal anuran communities in Southeast Coast Network parks. Natural Resource Report NPS/SECN/NRR-2013-XXX. National Park Service, Fort Collins, Colorado.

Collins, J. P., and A. Storfer. 2003. Global amphibian declines: Sorting the hypotheses. Diversity and Distributions 9:89–98.

Corn, P. S. 2005. Climate change and amphibians. Animal Biodiversity and Conservation. 28:59-67.

Dorcas, M., and W. Gibbons. 2008. Frogs and Toads of the Southeast. University of Georgia Press, Athens.

Echternacht, A. C., and L. D. Harris. 1993. The fauna and wildlife of the southeastern United States. Pages 81-116 *in* W.H. Martin, S.G. Boyce, and A.C. Echternacht, eds., Biodiversity of the Southeastern United States: Lowland terrestrial communities. John Wiley and Sons, New York, New York, USA.

Gibbs, J. P., and A. R. Breisch. 2001. Climate warming and calling phenology of frogs near Ithaca, New York, 1900-1999. Conservation Biology 15:1175-1178.

Hutchens, S. J., and C. S. DePerno. 2009. Efficacy of sampling techniques for determining species richness estimates of reptiles and amphibians. Wildlife Biology 15:113-122.

MacKenzie, D. I., J. D. Nichols, G. B. Lachman, S. Droege, J. A. Royle, and C. A. Langtimm. 2002. Estimating site occupancy when detection probabilities are less than one. Ecology 83: 2248-2255.

MacKenzie, D. I., J. D. Nichols, J. A. Royle, K. H. Pollock, L. A. Bailey, and J. E. Hines. 2006. Occupancy modeling and estimation. Elsevier, San Diego, California, USA.

Mitchell, J., and W. Gibbons. 2010. Salamanders of the Southeast. University of Georgia Press, Athens.

Montoya, J. M., and D. Raffaelli. 2010. Climate change, biotic interactions and ecosystem services. Philosophical Transactions of the Royal Society B 365:2013-2018.

Mohr, J. R., and M. E. Dorcas. 1999. A comparison of anuran calling patterns at two Carolina bays in South Carolina. Journal of the Elisha Mitchell Scientific Society 115:63-70.

NPSpecies - The National Park Service Biodiversity Database. Secure online version. https://science1.nature.nps.gov/npspecies/web/main/start (Park list: accessed 1/13/2013).

Olson, D. H., W. P. Leonard, and R. B. Bury (Eds.). 1997. Sampling amphibians in lentic habitats (Northwest Fauna 4). Society for Northwestern Vertebrate Biology, Olympia, WA, USA. 134pp.

Parmesan, C. 2007. Influences of species, latitudes, and methodologies on estimates of phonological response to global warming. Global Change Biology 13:1860-1872.

Petranka, J. W. 1998. Salamanders of the United States and Canada. Smithsonian Institution Press, Washington, DC, USA.

Theobald, D. M., D. L. Stevens, D. White, N. S. Urquhart, A. R. Olsen, and J. B. Norman. 2007. Using GIS to generate spatially balanced random survey designs for natural resource applications. Environmental Management 40:134-146.

Todd, M. J., R. R. Cocklin, and M. E. Dorcas. 2003. Temporal and spatial variation in anuran calling activity in the western Piedmont of North Carolina. Journal of the North Carolina Academy of Science. 119:103-110.

Todd, B. D., D. E. Scott, J. H. K. Pechmann, and J. W. Gibbons. 2011. Climate change correlates with rapid delays and advancements in reproductive timing in an amphibian community. Proceedings of the Royal Society B 278:2191-2197.

Wright, C. J. 2013. Summary of weather and climate monitoring in Southeast Coast Network parks, 2012. Natural Resource Data Series NPS/SECN/NRDS—2013/477. National Park Service, Fort Collins, Colorado.

U.S. Census Bureau. 2010. State & county QuickFacts: Georgia. http://quickfacts.census.gov (Accessed July 10, 2013).

Appendix A. Amphibian Species Detection Data

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

Scientific Name	Common Name	NPSpecies	ARD	VES
Anaxyrus terrestris	Southern Toad	X	X	
Acris gryllus	Southern Cricket Frog	X		X
Hyla chrysoscelis	Cope's Gray Treefrog	X		
Hyla cinerea	Green Treefrog	X	X	X
Hyla femoralis	Pine Woods Treefrog	X	X	
Hyla gratiosa	Barking Treefrog	X		
Hyla squirella	Squirrel Treefrog	X	X	X
Pseudacris crucifer	Spring Peeper	X	X	
Pseudacris nigrita	Southern Chorus Frog	X		
Pseudacris ocularis	Little Grass Frog	X	X	
Gastrophryne carolinensis	Eastern Narrow-mouthed Toad	X	X	
Lithobates grylio	Pig Frog	X	X	
Lithobates sphenocephalus	Southern Leopard Frog	X	X	X
Scaphiopus holbrookii	Eastern Spadefoot Toad	X		
Ambystoma talpoideum	Mole Salamander	X		
Amphiuma means	Two-toed Amphiuma	X		
Desmognathus auriculatus	Southern Dusky Salamander	X		
Eurycea quadridigitata	Dwarf Salamander	X		
Notophthalmus viridescens	Eastern Newt	X		

Table A-2. Amphibian species or species sign detected at each sampling location at Cumberland Island National Seashore, 2012.

	Sampling Location																													
Species	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**11**	**13**	**37**	**38**	**39**	**40**	**41**	**42**	**43**	**45**	**46**	**47**	**48**	**49**	**50**	**52**	**53**	**54**	**55**	**56**	**57**	**59**	**60**
Southern Toad	X	X	X	X	X	X			X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Southern Cricket Frog				X																									X		
Green Treefrog			X	X			X	X		X	X	X		X					X			X		X		X	X		X	X	X
Pine Woods Treefrog		X	X			X				X					X	X			X	X	X	X	X	X			X				
Squirrel Treefrog	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X			X	X	X	X	X	X	X	X	X	X	X	X	X
Spring Peeper				X									X						X			X				X	X				X
Little Grass Frog																			X			X									
Eastern Narrow-mouthed Toad																			X										X		
Pig Frog						X																									X
Southern Leopard Frog																			X										X		

Table A-3. Total number of larval and post-metamorphic detections of amphibian species during visual encounter surveys at Cumberland Island National Seashore, 2012.

	Species	**Number of Post-Metamorphic Detections**	**Number of Larval Detections**	**Species Total Detections**
Anura	Southern Cricket Frog	3	0	**3**
	Green Treefrog	37	0	**37**
	Squirrel Treefrog	70	0	**70**
	Southern Leopard Frog	1	0	**1**
	Total Detections	**111**	**0**	**111**

Appendix B. Distribution Maps for Amphibian Species Encountered

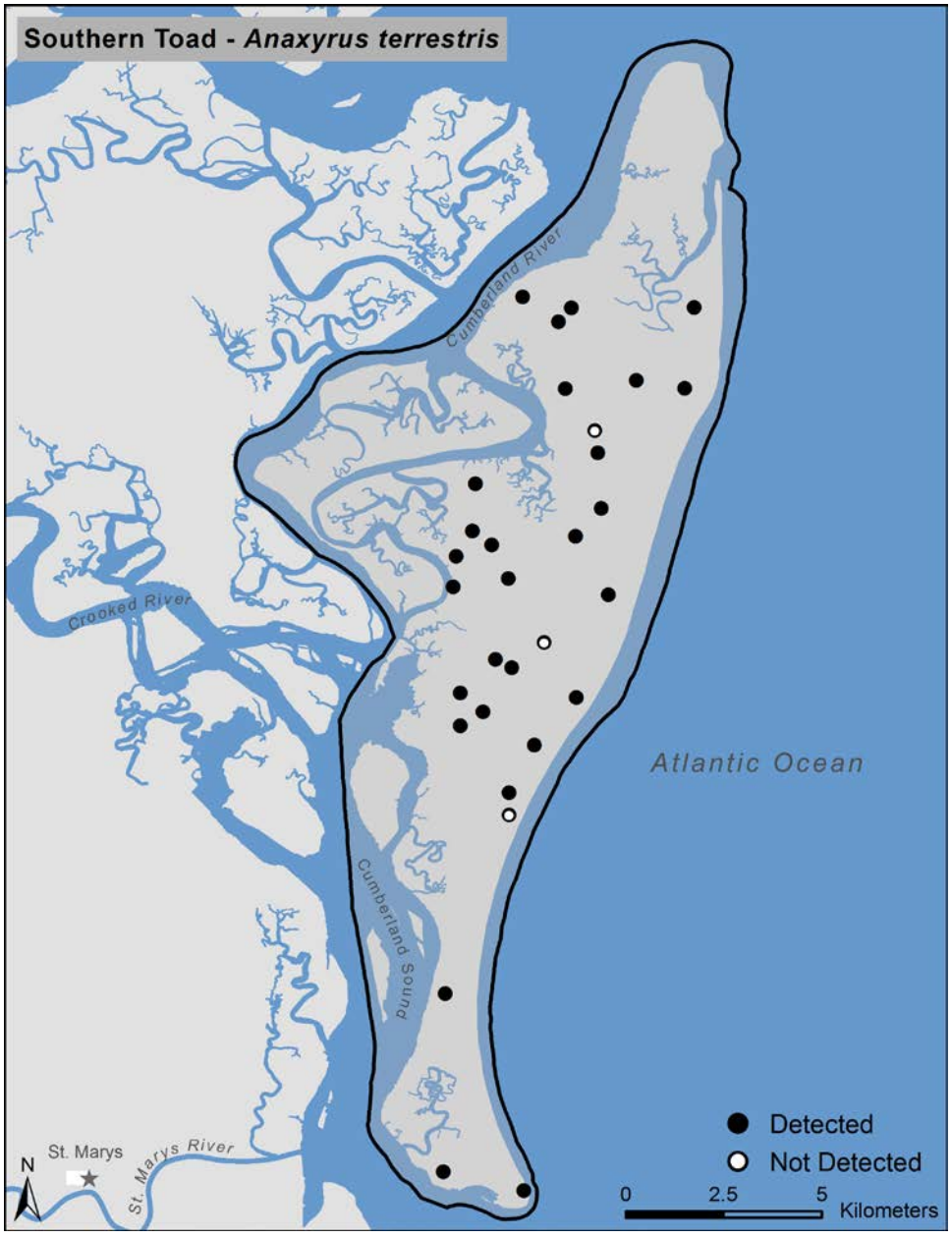


Figure B-1. Sampling locations where Southern toad (*Anaxyrus terrestris*) was detected at Cumberland Island National Seashore, 2012.

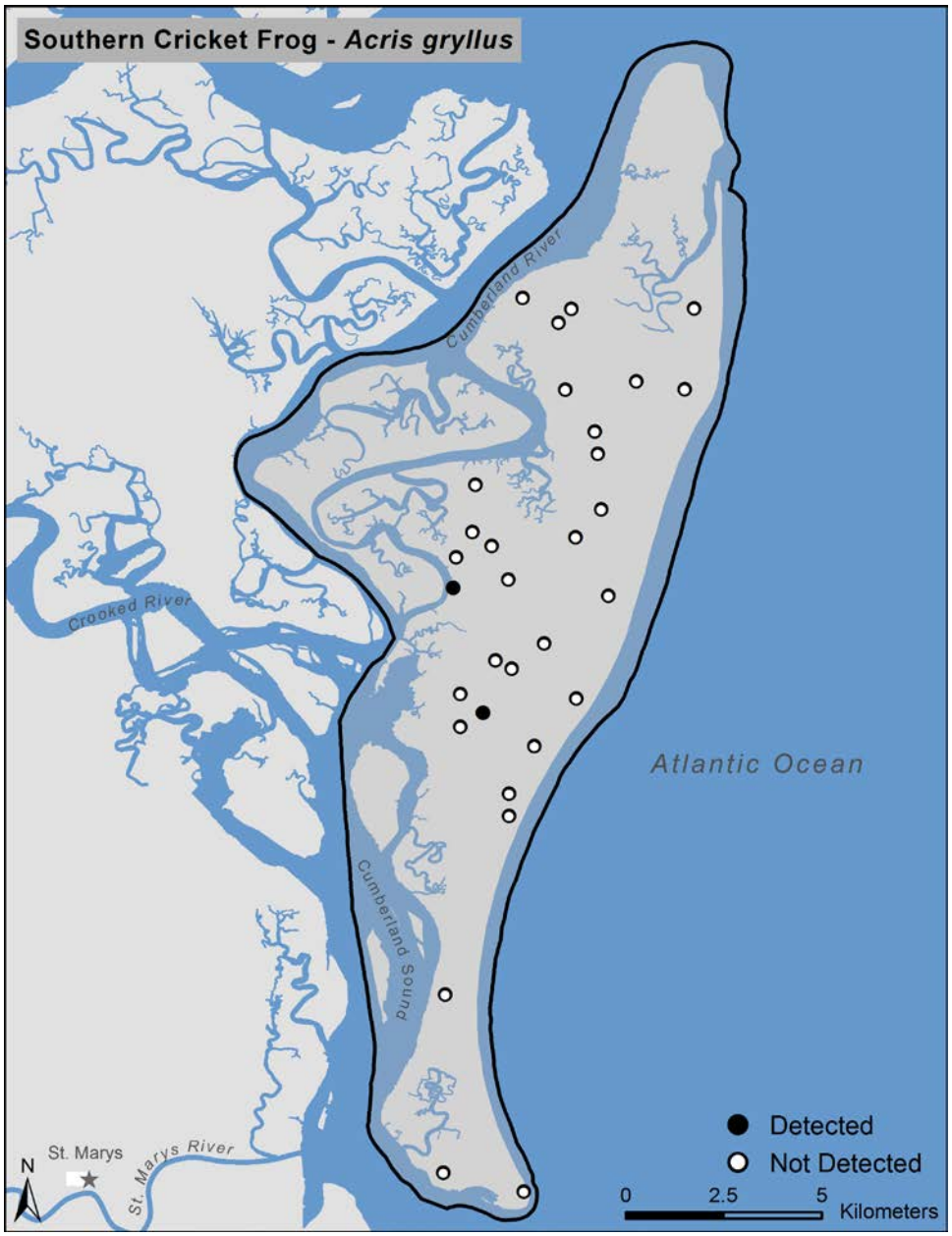


Figure B-2. Sampling locations where Southern cricket frog (*Acris gryllus*) was detected at Cumberland Island National Seashore, 2012.

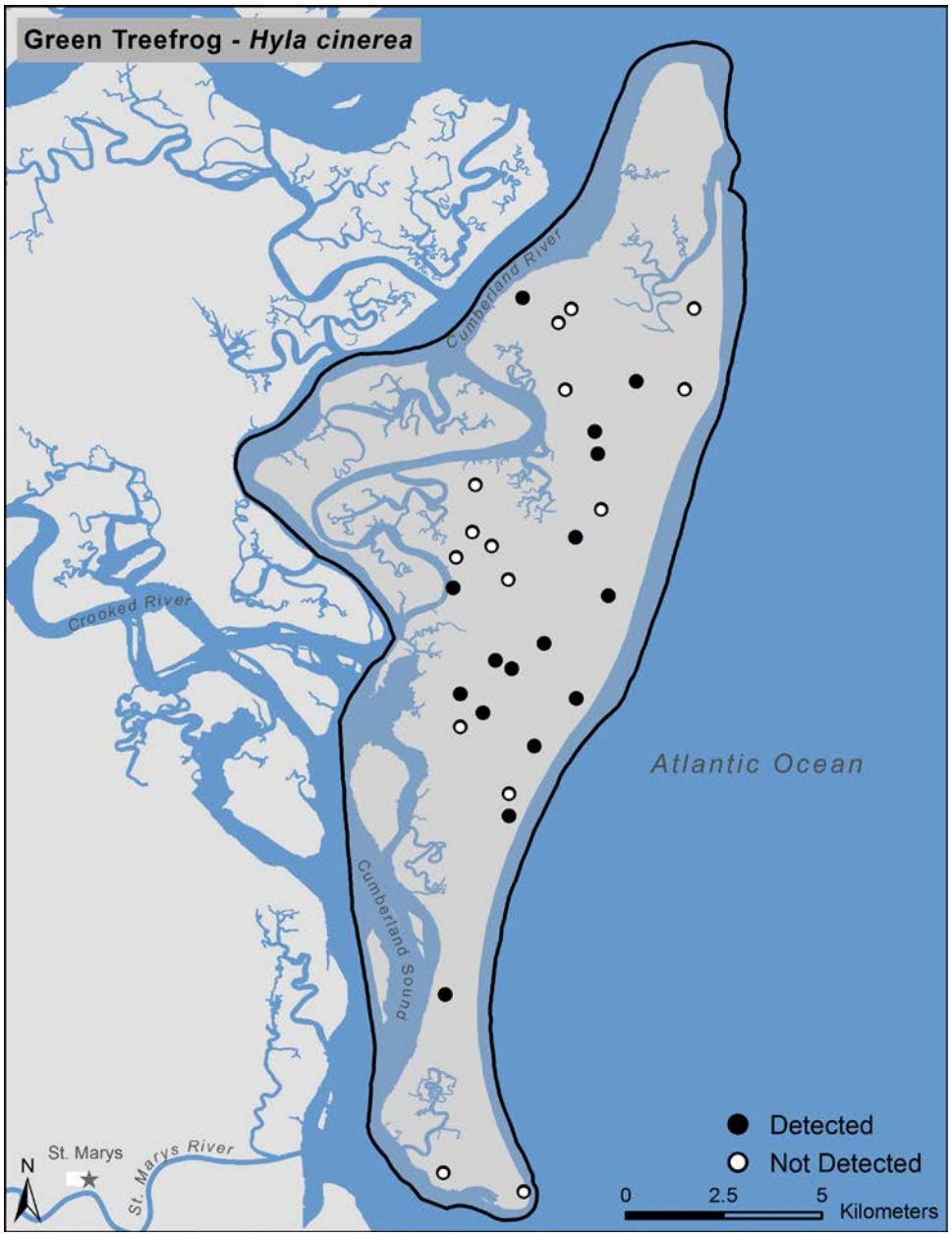


Figure B-3. Sampling locations where green treefrog (*Hyla cinerea*) was detected at Cumberland Island National Seashore, 2012.

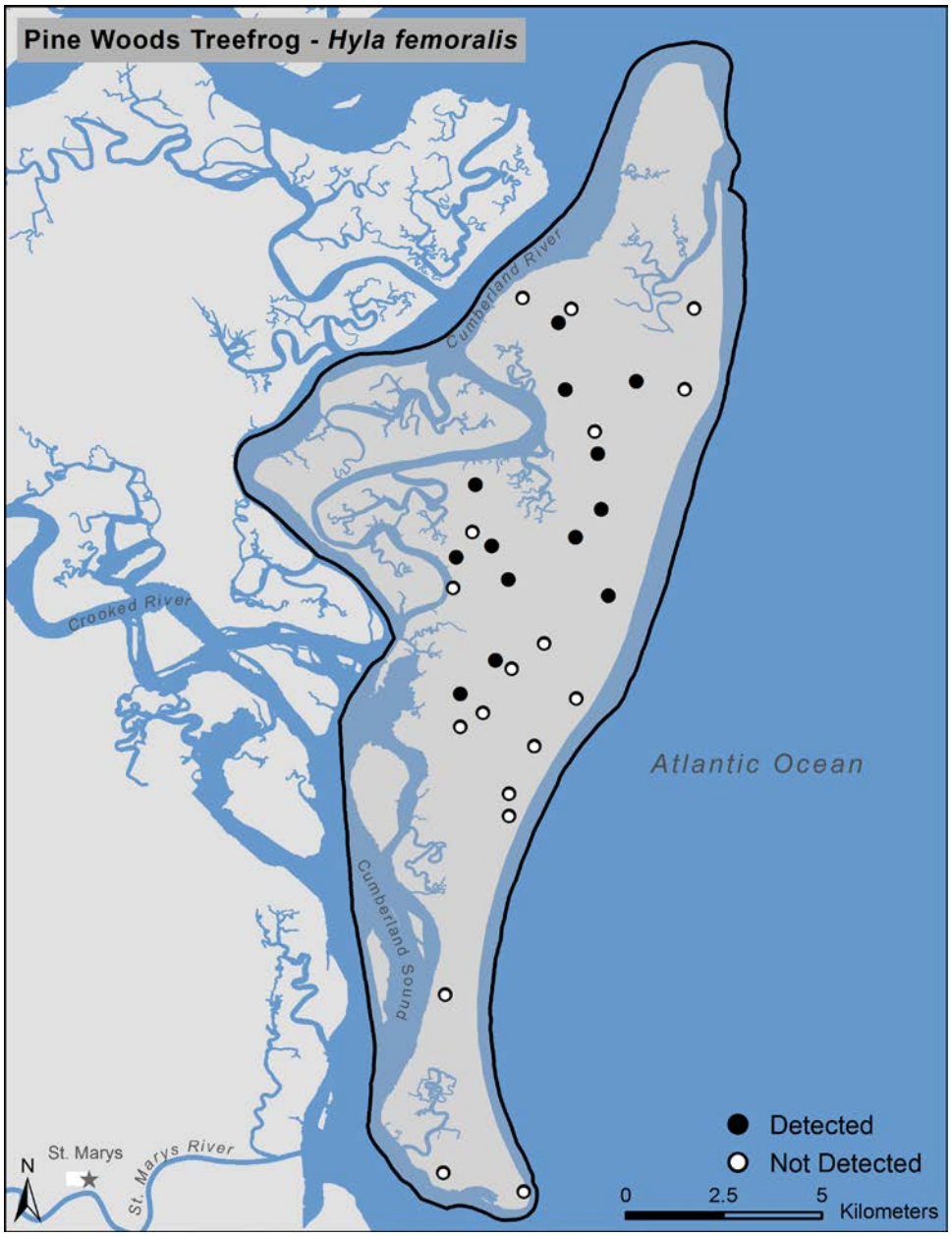


Figure B-4. Sampling locations where pinewoods treefrog (*Hyla femoralis*) was detected at Cumberland Island National Seashore, 2012.

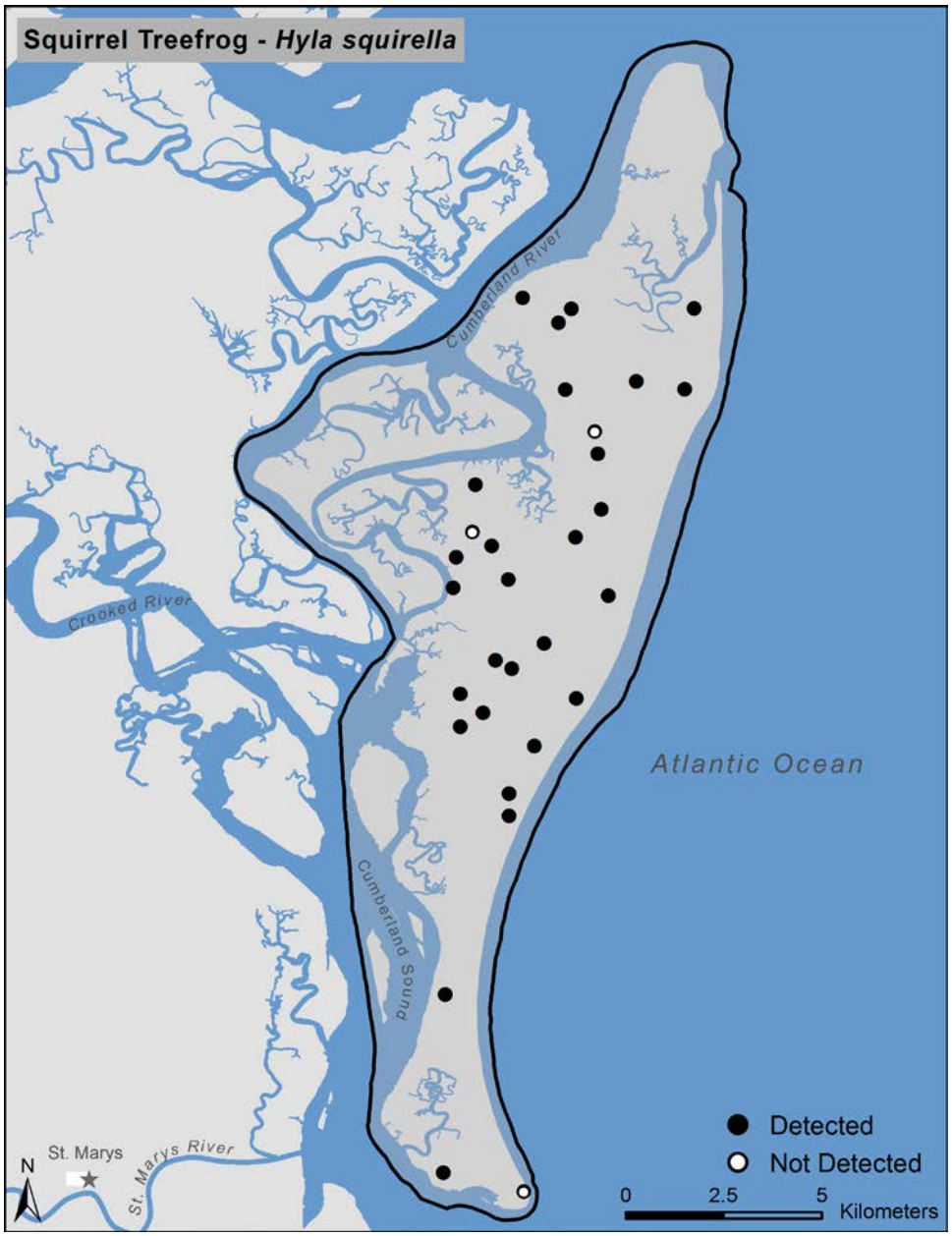


Figure B-5. Sampling locations where squirrel treefrog (*Hyla squirella*) was detected at Cumberland Island National Seashore, 2012.

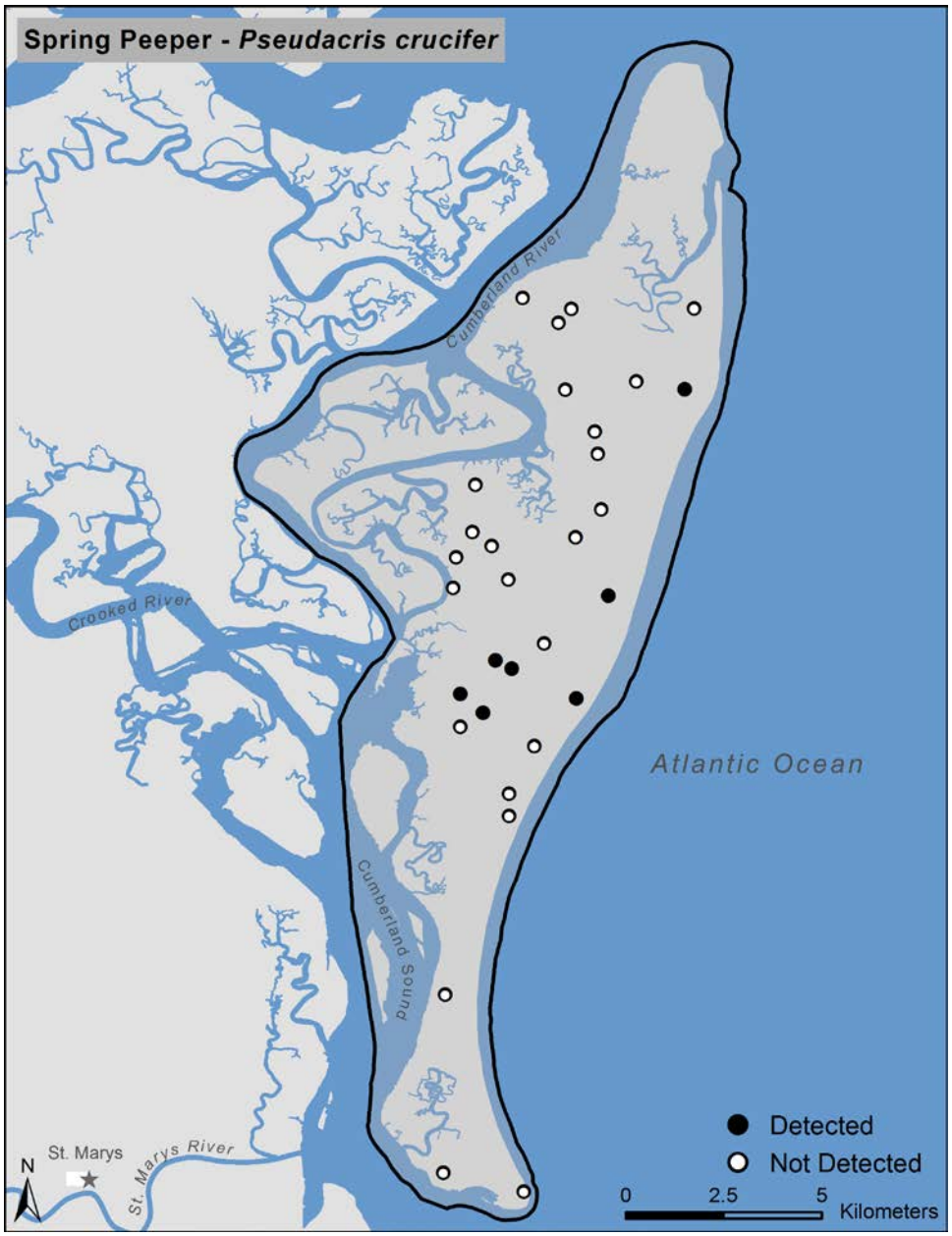


Figure B-6. Sampling locations where spring peeper (*Pseudacris crucifer*) was detected at Cumberland Island National Seashore, 2012.

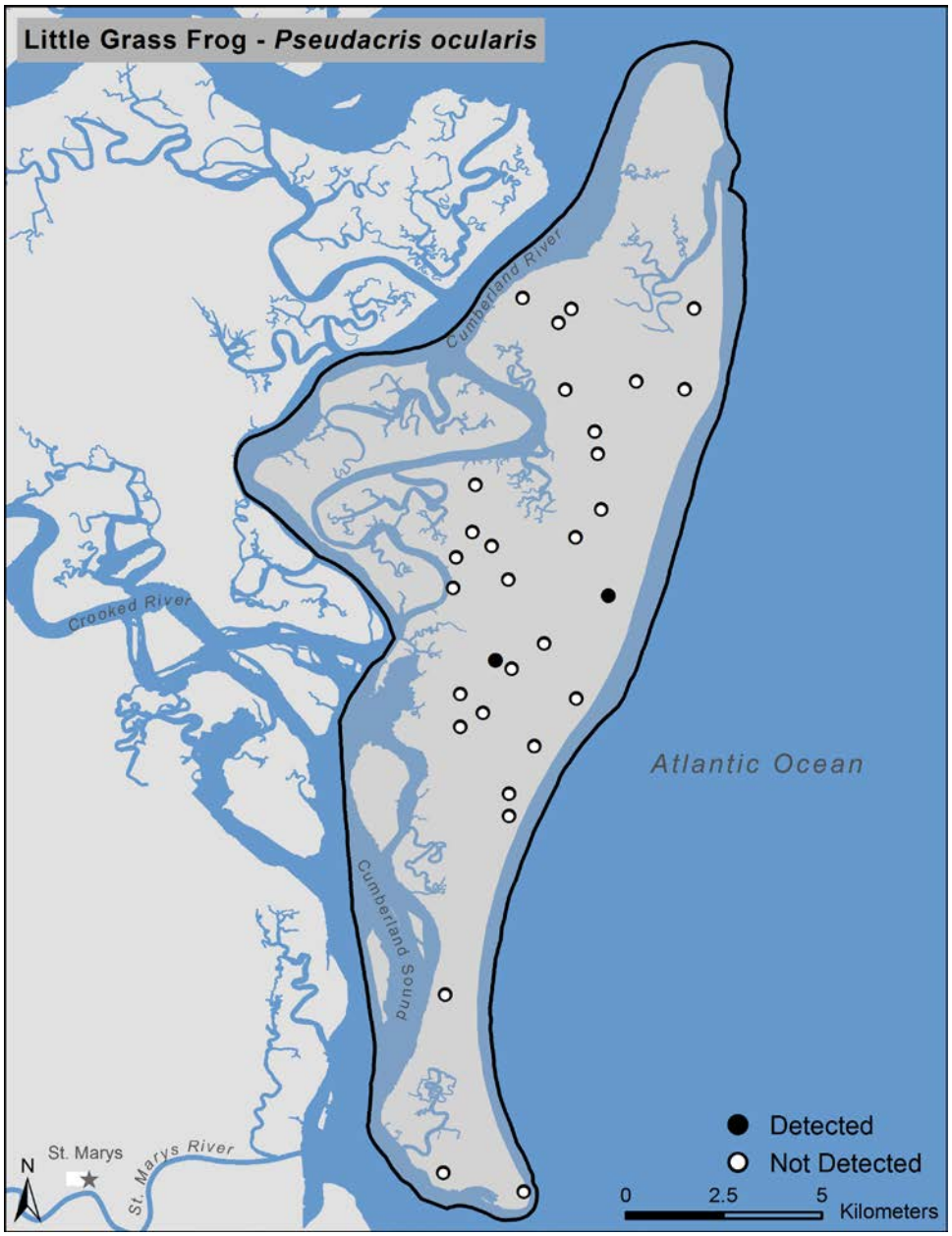


Figure B-7. Sampling locations where little grass frog (*Pseudacris ocularis*) was detected at Cumberland Island National Seashore, 2012.

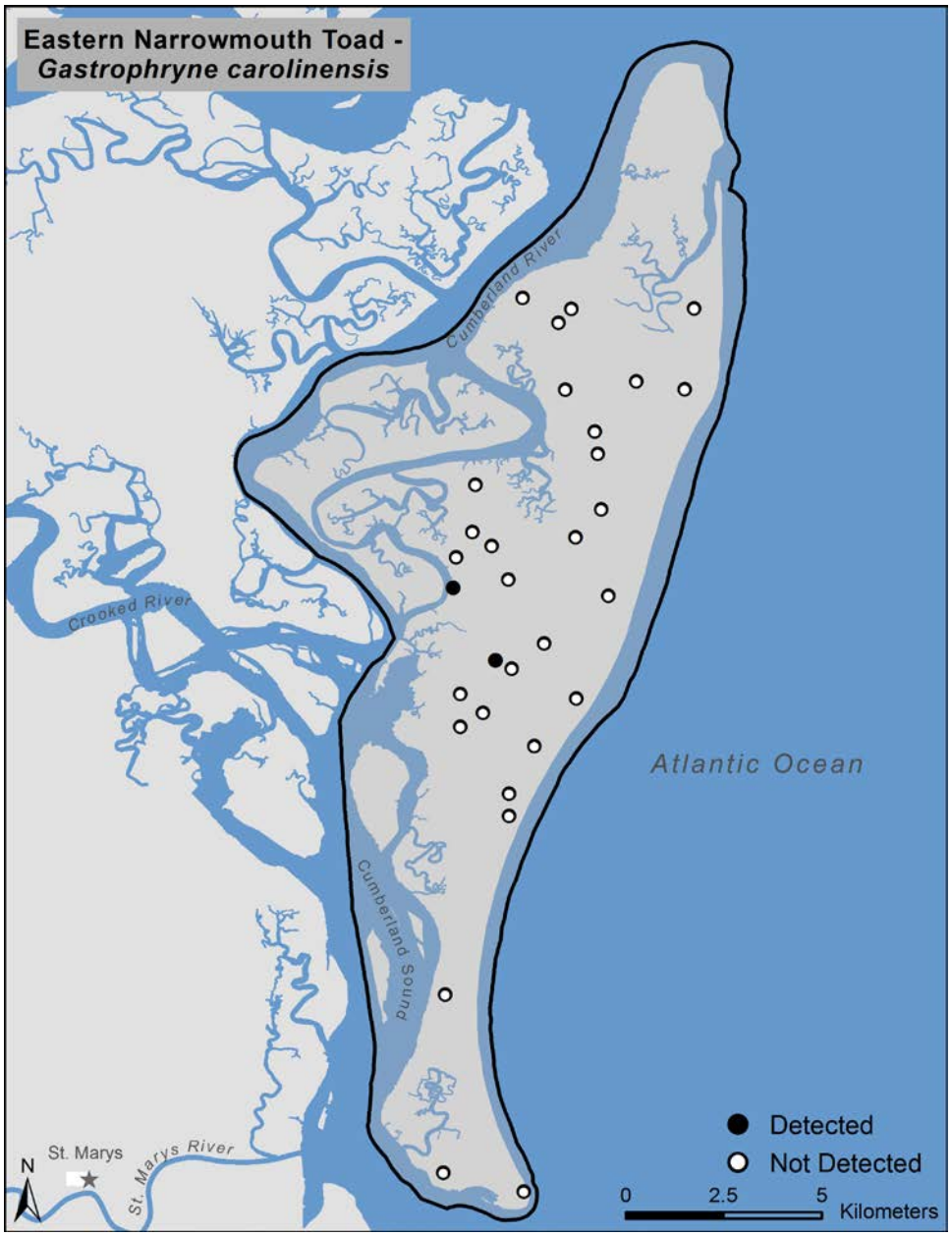


Figure B-8. Sampling locations where Eastern narrow-mouthed toad (*Gastrophryne carolinensis*) was detected at Cumberland Island National Seashore, 2012.

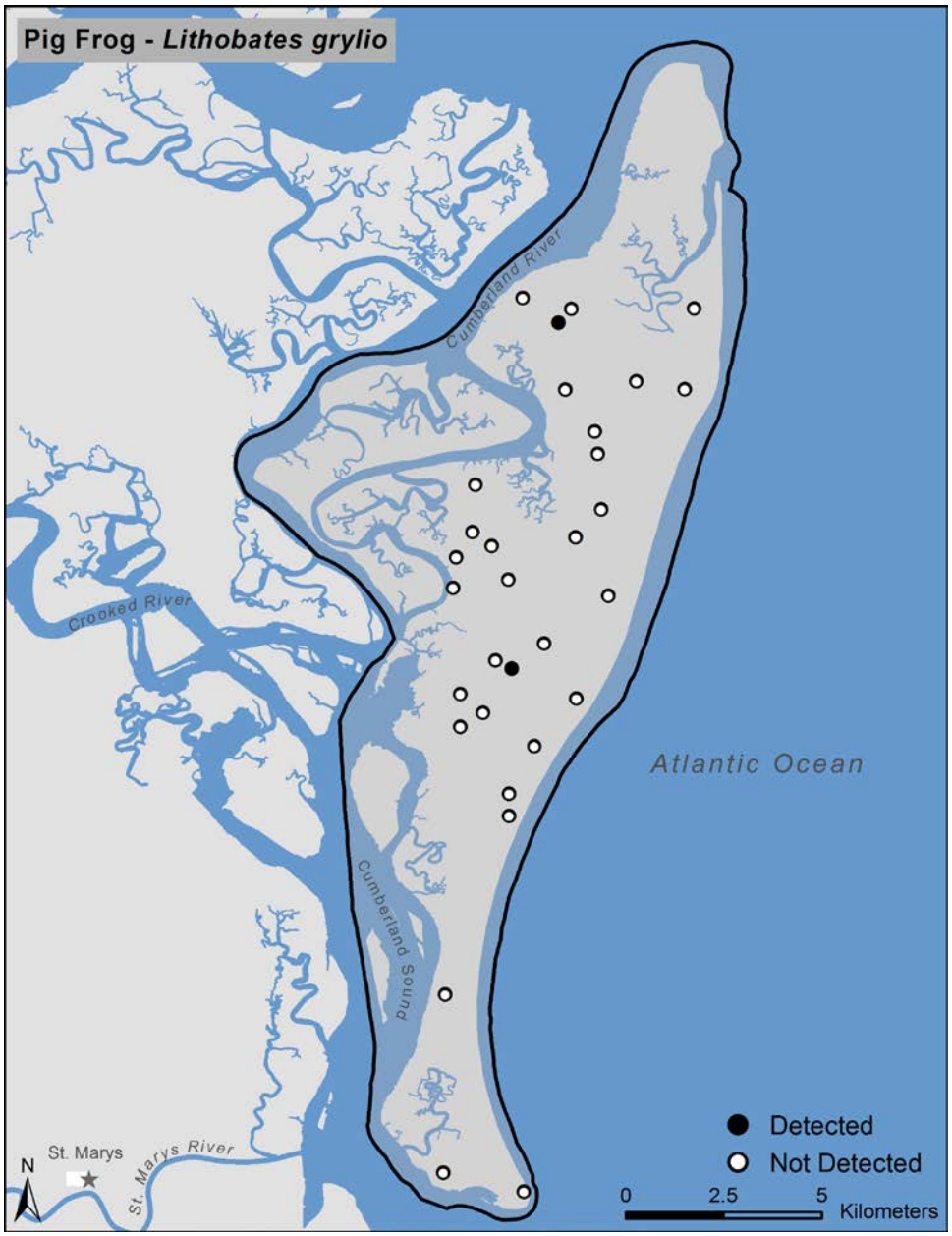


Figure B-9. Sampling locations where pig frog (*Lithobates grylio*) was detected at Cumberland Island National Seashore, 2012.

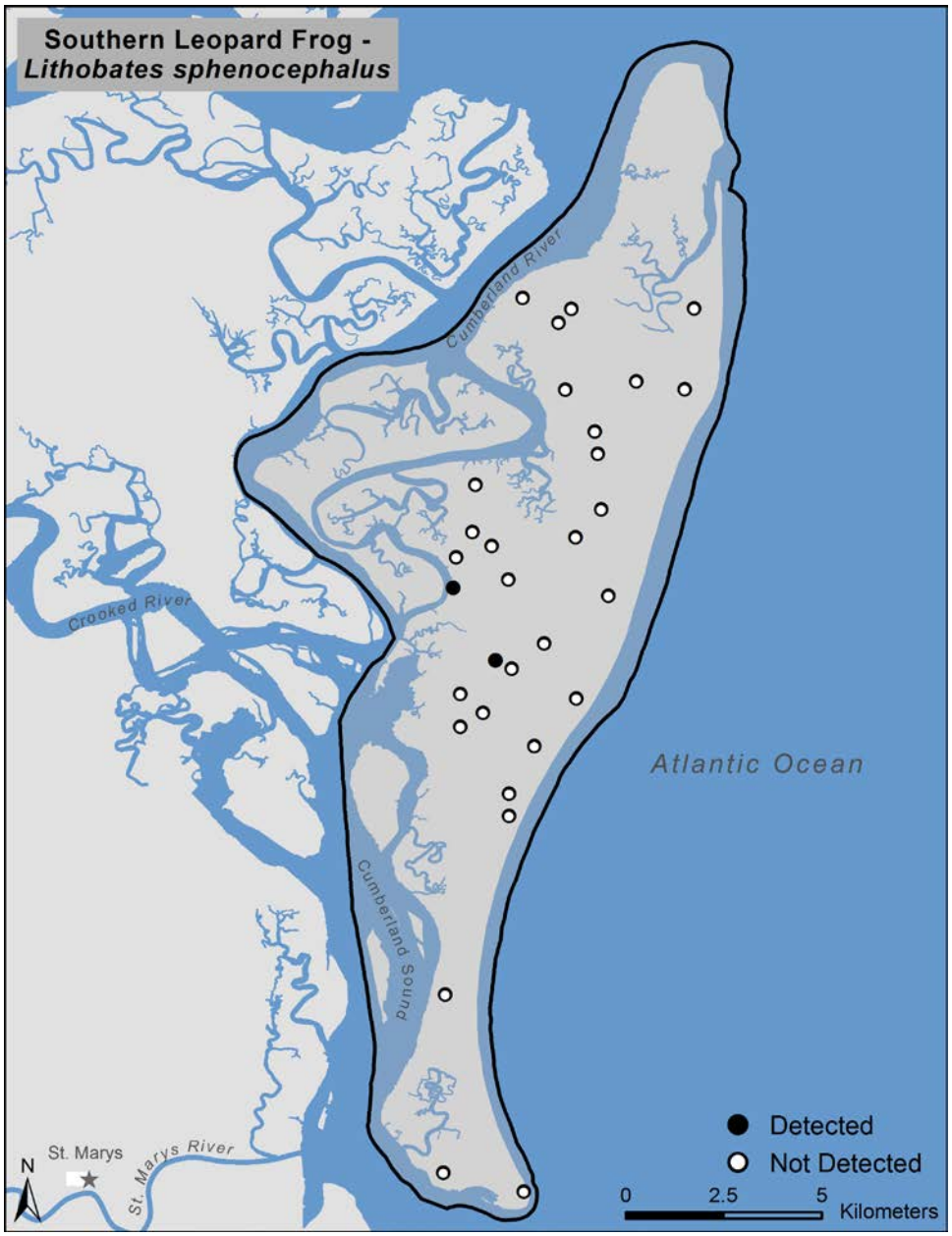


Figure B-10. Sampling locations where Southern leopard frog (*Lithobates sphenocephalus*) was detected at Cumberland Island National Seashore, 2012.

Appendix C. Reptile Species Detection Data

Cumberland Island has 44 known reptile species, consisting of one species of *Crocodilia*, 29 species in *Squamata* (e.g. lizards, snakes, geckos, and skinks), and 14 species in *Testudines* (turtles and tortoises) (Table C-1). We confirmed the presence of the Five-lined Skink (*Eumeces fasciatus*) on CUIS in 2012, and it was added to the Park reptile species list (Table C-3).

We detected 137 reptiles or reptile signs from 12 different species during visual encounter surveys in 2012 (Table C-1, Figure C-1). The green anole (*Anolis carolinensis*) and the ground skink (*Scincella lateralis*) had the highest frequency of occurrence among reptile species, and each was found at 48% of the sampling locations (Table C-2). The Eastern fence lizard (*Sceloporus undulatus*) was detected at 35% of the sampling locations at CUIS. The ground skink and the green anole also had the highest relative abundance, accounting for 39% and 38% of all reptile sightings, respectively. The Eastern Fence Lizard accounted for 12% of the reptiles sighted (Figure C-1).

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

Scientific Name	Common Name	NPSpecies	VES
Alligator mississippiensis	Alligator	X	X
Ophisaurus compressus	Island Glass Lizard	X	
Ophisaurus ventralis	Eastern Glass Lizard	X	
Cemophora coccinea	Scarlet Snake	X	
Coluber constrictor	Black Racer	X	X
Diadophis punctatus	Ringneck Snake	X	
Elaphe guttata	Corn Snake	X	
Elaphe obsoleta	Black Rat Snake	X	
Farancia abacura	Mud Snake	X	
Lampropeltis getula	Common Kingsnake	X	
Lampropeltis triangulum	Milk Snake	X	
Masticophis flagellum	Coachwhip	X	X
Nerodia fasciata	Southern Watersnake	X	
Nerodia fasciata fasciata	Banded Watersnake	X	
Opheodrys aestivus	Rough Green Snake	X	X
Rhadinaea flavilata	Pine Woods Snake	X	
Storeria occipitomaculata	Red-bellied Snake	X	X
Thamnophis sauritus	Eastern Ribbon Snake	X	
Thamnophis sirtalis	Garter Snake	X	X
Sceloporus undulatus	Eastern Fence Lizard	X	X
Anolis carolinensis	Green Anole	X	X
Eumeces egregius	Mole Skink	X	

Eumeces fasciatus	Five-lined Skink		X
Eumeces inexpectatus	Southeastern Five-lined Skink	X	X
Eumeces laticeps	Broad-headed Skink	X	
Scincella lateralis	Ground Skink	X	X
Aspidoscelis sexlineatus	Six-lined Racerunner	X	
Agkistrodon piscivorus	Cottonmouth	X	X
Crotalus adamanteus	Eastern Diamondback Rattlesnake	X	
Crotalus horridus	Timber Rattlesnake	X	
Caretta caretta	Loggerhead Sea Turtle	X	
Chelonia mydas	Green Sea Turtle	X	
Eretmochelys imbricata	Hawksbill Sea Turtle	X	
Lepidochelys kempii	Kemp's Ridley Sea Turtle	X	
Chelydra serpentina serpentina	Eastern Snapping Turtle	X	
Dermochelys coriacea	Leatherback Sea Turtle	X	
Deirochelys reticularia reticularia	Eastern Chicken Turtle	X	
Malaclemys terrapin centrata	Carolina Diamondback Terrapin	X	
Pseudemys nelsoni	Florida Red-bellied Cooter	X	
Trachemys scripta scripta	Yellow-bellied Slider	X	
Kinosternon baurii	Striped Mud Turtle	X	
Kinosternon subrubrum	Eastern mud turtle	X	
Gopherus polyphemus	Gopher Tortoise	X	
Apalone ferox	Florida Softshell Turtle	X	

Table C-2. Reptilian species or species sign detected at each sampling location at Cumberland Island National Seashore, 2012.

	Sampling Location																														
Species	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**11**	**13**	**37**	**38**	**39**	**40**	**41**	**42**	**43**	**45**	**46**	**47**	**48**	**49**	**50**	**52**	**53**	**54**	**55**	**56**	**57**	**59**	**60**
Alligator																													X		
Black Racer												X			X																
Coachwhip															X																
Rough Green Snake							X																								
Red-bellied Snake							X																								
Garter Snake																						X									
Eastern Fence Lizard	X			X	X	X	X			X		X			X		X										X	X			
Green Anole			X	X	X			X		X		X		X			X				X	X		X	X	X	X		X		
Five-lined Skink									X																						
Southeastern Five-lined Skink										X																	X				
Five-lined or Southeastern Five-lined Skink				X								X																			
Ground Skink		X		X	X	X	X		X	X	X			X		X	X			X			X			X		X			
Eastern Cottonmouth					X																										
Snake Skin						X																									

Table C-3. New amphibian species detected at Cumberland Island National Seashore in 2012 and recommended NPSpecies classifications.

Scientific Name	Common Name	Abundance	Residency	Nativity	Pest	Management Priority	Exploitation Concerns
Eumeces fasciatus	Five-lined Skink	Unknown	Resident	Native	No	No	No

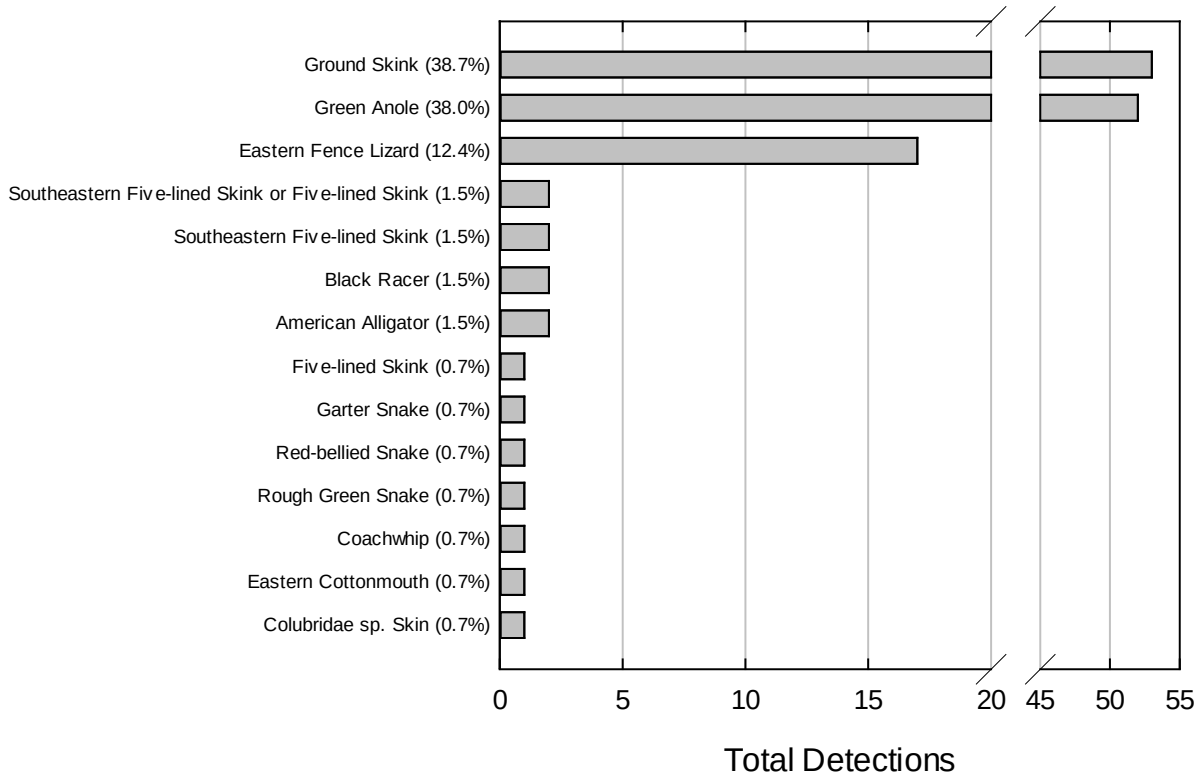


Figure C-1. Number of individual reptiles and reptile signs detected and percent species composition during visual encounter surveys at Cumberland Island National Seashore, 2012. Based on n=137 detections.