



Monitoring Amphibians in Gulf Coast Network Parks

Protocol Narrative—Version 2.0

Natural Resource Report NPS/GULN/NRR—2018/1742



ON THE COVER

Gulf Coast toad, *Incilius nebulifer*, in the Gulf Coast Network

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Change History

Version numbers will be incremented by a whole number (e.g., version 1.3 to version 2.0) when a change is made that significantly alters project requirements, procedures, continuity of the data, or interpretation of the data. Version numbers will be incremented by decimals (e.g., version 1.6 to version 1.7) when there are minor modifications that do not affect project requirements, procedures, data continuity or data interpretation.

Attribution notes: The Gulf Coast Network's first ecologist, Robert Woodman, led the development of protocol version 1, with major assistance from co-authors. The network's second ecologist, Jane Carlson, was responsible for updating, rewriting, and finalizing content for version 2, again with substantial co-author guidance.

Revision log:

Revision Date	Author	Changes Made and Justification	New Version #
5/2018	Jane Carlson	Version 1 was re-written to reflect the transition from a pilot project to the final, long-term monitoring project. The pilot design was modified based on internal review and power analysis results. Major changes to the design include (1) all but three parks were removed, and one new site was added to each of two parks; (2) several sampling methods were removed; (3) the arrangement of pipes and coverboards within sites was modified; and (4) the frequency of sampling was changed from monthly to alternate months. For the protocol narrative itself, the following major changes were made: (1) monitoring objectives were rewritten to be more directly linked to analyses and realities of the GULN approach; (2) data management section was rewritten; (3) the analysis and reporting section was rewritten; (4) figures and tables were changed; and (5) the document was updated to reflect new standards for formatting and content for protocol narratives.	2.0
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Executive Summary

The Inventory and Monitoring Division (IMD) of the National Park Service tracks the condition of natural resources on park lands through their Vital Signs Monitoring Program. Vital signs, in this context, include species, groups of organisms or natural processes that serve as indicators of ecosystem health. To implement the monitoring program, parks are grouped into regional networks that coordinate vital sign selection, design monitoring plans, and conduct long-term monitoring according to that plan. The Gulf Coast Network (GULN) of the IMD serves eight parks in the Gulf Coast region, and one of its highest priority vital signs is amphibians. Key reasons for monitoring amphibians are that (1) they are known to be highly sensitive to environmental conditions; (2) in and around the Gulf Coast region, amphibian diversity is high and includes many geographically restricted species; (3) amphibian populations are in decline across the globe, due to anthropogenic influences and environmental change. Thus, long-term data on amphibians provide reference points for resource condition in parks and can add breadth to regional, national and world-wide datasets.

As described in this monitoring protocol, the Gulf Coast Network uses coverboards and PVC pipes for monitoring amphibians in focal habitats. When placed on the ground or in trees, respectively, these objects create artificial cover for a range of amphibian species, providing a favorable microclimate and allowing the animals to come and go unharmed. These cover objects are also easy to check, inexpensive and do not require disturbing logs or vegetation while monitoring. Each pipe or board is checked during park visits that take place every other month. In addition to recording the amphibian species present and the number of each, the crew records environmental conditions on-site, including temperature in and around pipes or boards, relative humidity, and water level in the nearest water body. Data on rainfall and temperature in the days prior to sampling are obtained from nearby weather stations.

The network uses these techniques to address the following two monitoring objectives:

1. Determine species composition of the amphibian communities that use the monitored cover objects (PVC pipes or coverboards) at each site, and determine species richness for native and exotic species separately.
2. Determine the frequency (yes/no detected) and relative abundance (counts per pipe or board) of the more commonly encountered amphibian species at each site, and determine trends over time.

The Gulf Coast Network monitors amphibians in seven sites distributed across three parks: Jean Lafitte National Historical Park and Preserve, Gulf Islands National Seashore and San Antonio Missions National Historical Park. Sites were specifically targeted and do not provide park-wide inference. Further, only three GULN parks are included, because pilot data in the other five parks showed that the two selected techniques were ineffective.

The Gulf Coast Network's Amphibian Monitoring Program is presented here in two parts: the protocol narrative, which summarizes the monitoring approach, rationale and required resources; and

a separate set of Standard Operating Procedures (SOPs), which detail the steps in collecting, managing, and disseminating the project's findings. The protocol's intent is to provide the framework and methods for documenting and reporting on park amphibians that use the monitored cover objects over the long term. To the extent possible, any observed trends are considered in light of park management actions, habitat alterations, and other stressors.

Acknowledgments

This protocol could not have been completed without assistance from both within and outside of the National Park Service (NPS). The authors gratefully acknowledge the following people: J. Whitfield Gibbons, J. D. Willson, and T. Tuberville of the University of Georgia—Savannah Ecological Laboratory (SREL); Susan Walls, Hardin Waddle and Tim Craig of the U.S. Geological Survey (USGS); and Joe Mitchell. We also thank the many park employees and VIP volunteers who participated in sampling during the development and pilot implementation of this protocol, including Kurt Foote and Lisa McInnis (Natchez Trace Parkway [NATR]), Nancy Walters (Jean Lafitte National Historical Park and Preserve [JELA]), Virginia DuBow (Vicksburg National Military Park [VICK]), Greg Mitchell (San Antonio Missions National Historical Park [SAAN]), Rolando Garza (Palo Alto Battlefield National Historical Park [PAAL]), and Riley Hoggard (Gulf Islands National Seashore [GUIS]).

Background and Objectives

Background and History

The Inventory and Monitoring Division (IMD) of the National Park Service (NPS) is responsible for tracking the condition of significant natural resources in U.S. National Park System units. There are more than 270 properties monitored through this program, and they have been divided into 32 networks each served by a single office. All 32 networks share the same suite of programmatic goals that motivate the planning, design, and implementation of integrated natural resource monitoring projects. As stated by Fancy et al. (2009), these goals are to:

- determine the status and trends of selected indicators of park ecosystem conditions to make better-informed decisions and to work more effectively with other agencies and individuals for the benefit of park resources;
- provide early warning of abnormal conditions of selected resources to help develop effective mitigation measures and reduce costs of management;
- provide data to better understand the dynamic nature and condition of park ecosystems and to provide reference points for comparisons with other altered environments;
- provide data to meet certain legal and Congressional mandates related to natural resource protection and visitor enjoyment; and
- provide a means of measuring progress towards performance goals.

Each network in the Inventory and Monitoring Division follows an approach called “Vital Signs Monitoring.” In this context, vital signs are defined as a representative subset of biological, physical or chemical processes and elements that are indicative of the “overall health or condition of park natural resources (Fancy et al. 2009).” The Gulf Coast Network (Figure 1) has identified a suite of 19 vital signs, including amphibians, that are highest priority for monitoring. These vital signs were selected through a collaborative process involving network staff, key stakeholders, and the parks, as outlined in the Gulf Coast Network Monitoring Plan (Segura et al. 2007). Amphibians are broadly sensitive to environmental change and were selected as a high priority vital sign by other networks in the inventory and monitoring division.

This protocol narrative outlines the means by which the Gulf Coast Network collects, manages, and reports monitoring data for its amphibian vital sign. The Gulf Coast Network includes eight national park system units (Figure 1) with a total area of approximately 101,790 hectares (251,528 acres [ac]). The network originally planned to monitor amphibian populations in all eight park units using a standardized suite of methodologies and sampling designs. Based on park inventory results and recommendations (e.g., Seigel and Doody 1996; Anderson and Seigel 2003), three commonly used methods were selected for testing in most GULN parks during the project’s pilot phase (2008–2017). These methods were PVC pipes on trees, coverboards on the ground, and minnow traps in standing water. The pilot work revealed that capture rates in minnow traps were too low to justify their continued use (for more details, see Carlson [2018], a supplemental document online). Further, pilot

work showed that the GULN monitoring approach provided sufficient data for trend analyses in only three of the eight parks. As such, the GULN protocol narrative and SOPs describe how PVC pipes and coverboards are used to monitor amphibians in Jean Lafitte National Historical Park and Preserve (JELA), Gulf Island National Seashore (GUIS), and San Antonio Missions National Historical Park (SAAN).

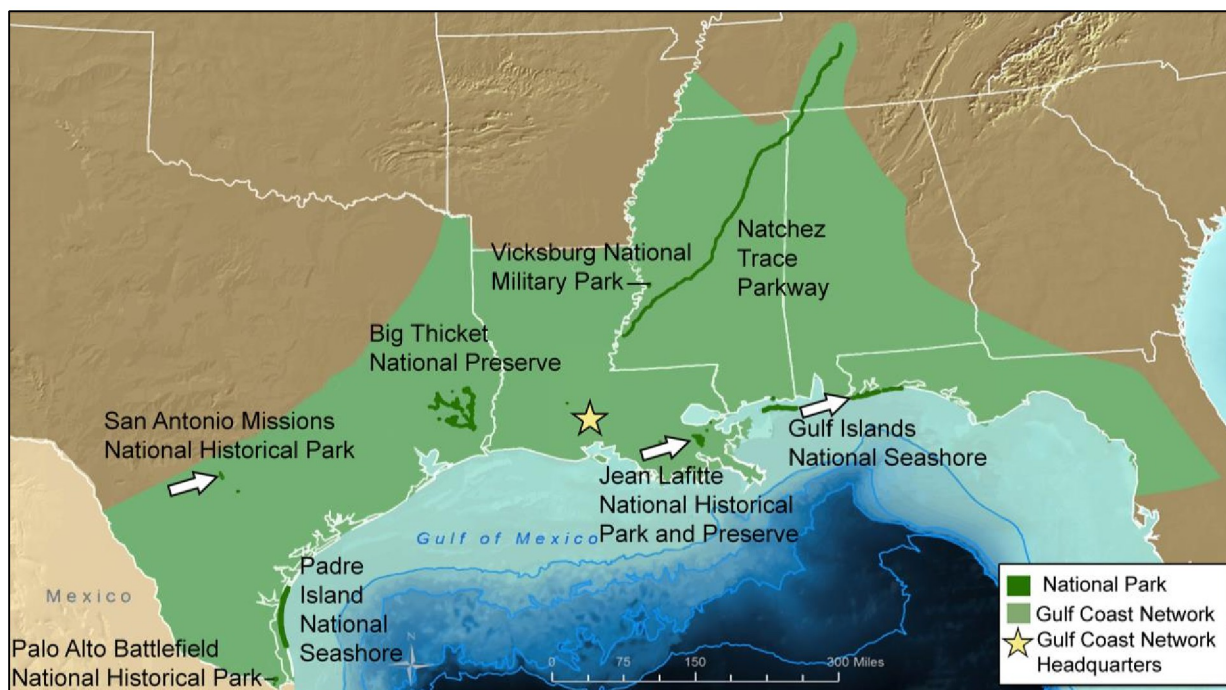


Figure 1. The area covered by the Gulf Coast Network of the National Park Service (light green shading). The network is headquartered in Lafayette, Louisiana. After extensive pilot studies, the network determined that amphibian monitoring using artificial cover objects was viable in only three of its eight national park units. The eight network units are labeled and shaded dark green, and the three units where amphibian monitoring takes place are indicated with white arrows.

Parks and Ecosystems where Gulf Coast Network Monitors Amphibians

Each monitored park is in a different ecoregion of the United States. However, all three parks have some forested areas adjacent to fresh waterbodies, which are the habitats targeted by the network. The study site locations within each park are shown in Appendix A.

The eastern-most park is Gulf Island NS, in the Southern Coastal Plain ecoregion (EPA 2013). Gulf Islands NS consists of barrier islands and adjacent mainland units along the upper Gulf of Mexico coast from Pensacola, Florida, west to Ocean Springs, Mississippi (excluding Alabama). The mainland unit in Mississippi is called Davis Bayou, and the mainland unit in Florida is called Naval Live Oaks. Both mainland areas contain diverse habitats including coastal wetlands and riparian corridors, ponds and marshes, pine flats, sand-dune scrub habitats, and coastal oak and pine lowland forests. The island units in Florida are on Santa Rosa Island and Perdido Key, and the island units in Mississippi are Horn Island, East Ship Island, West Ship Island and Petit Bois Island. The habitat

where amphibians are monitored at Gulf Islands NS is the coastal oak and pine lowland scrub/forest in the Naval Live Oaks Area.

Jean Lafitte NHP&P is west of Gulf Islands NS, in the Mississippi Alluvial Plain ecoregion (EPA 2013). There, amphibian monitoring focuses on the Barataria Preserve, which comprises 7,202 hectares (17,796 ac) of coastal wetland located southwest of New Orleans, Louisiana. Habitats include mixed hardwood and bald cypress-based wet forest, grading southerly down to a floating-marsh system (the coastal *flotant marsh* of southern Louisiana). These habitats are dissected by historic dredged canals. The majority of the preserve is variably flooded and is subject to sporadic and sometimes extensive salt-water intrusion during coastal storms. The preserve is increasingly affected by residential development on adjacent lands, which creates water-flow barriers and affects park water quality. The habitat selected for amphibian monitoring at Jean Lafitte NHP&P is the bottomland hardwood forest.

The western-most park is San Antonio Missions NHP, in the East Central Texas Plains ecoregion (EPA 2013). The primary unit at the park is the historic Spanish Missions located along the San Antonio River extending south from the city-center of San Antonio, Texas. The Missions encompass approximately 190 hectares (469.5 ac) of urban park land with small fragments of the historical riparian scrub along the San Antonio River and mixed forest habitat. The unit also includes reclaimed agricultural fields and a historic irrigation system (the acequia canals). The Missions are heavily affected by adjacent high-density urban development. The habitats selected for monitoring at San Antonio Missions NHP are the mixed forests and woodlands.

Rationale for Monitoring Amphibian Assemblages in Gulf Coast Network Parks

There are three major reasons why amphibians are particularly well suited for vital signs monitoring on Gulf Coast Network parks. First, amphibians are known to be highly sensitive to environmental conditions, due to their permeable skin and, for many, their biphasic (aquatic and terrestrial) life-stages. They also tend to be associated with other key natural resources, including ponds, wetlands, and forest areas. This makes them valuable as ecological indicators. Second, the Gulf Coast and adjacent southeastern United States have high amphibian diversity, which includes numerous species with very limited distribution (Duellman and Sweet 1999; Dorcas and Gibbons 2008; Mitchell and Gibbons 2010). Third, many amphibian populations are in decline across the globe, especially in the southeastern United States, due to increasing regional anthropogenic influence and environmental change (Lannoo 2005; Wake and Vredenberg 2008; Hof et al 2011; Adams et al. 2013; Barrett et al. 2014). Therefore, there is a great need to collect long-term data on amphibian abundance and diversity, both in and outside of park properties (Walls 2014).

Because GULN parks include protected natural areas within a human-impacted landscape, they provide essential habitat for amphibians in the region. However, park habitats are threatened by three major stressors that may alter the integrity of ecosystems and natural resources:

1. park units may be isolated and fragmented to varying degrees, limiting animal movement and gene flow;

2. the Gulf Coast region experiences storm events that can substantially affect the land, water quality and wildlife; and
3. the Gulf Coast region is increasingly subject to human development, which can directly affect park resources through environmental contamination, introduction of exotic species, introduction of diseases, road mortality, and collection or harvest of wildlife.

Threats to Amphibians in Gulf Coast Network Parks

There are many serious threats to the persistence of amphibian populations worldwide. These threats include fragmentation and loss of habitat, climate change, environmental contamination, disease and parasitism, invasive species, illegal collection or harvest, and mortality due to roads. On a global scale, these stressors can cause populations to crash, geographical ranges to shrink, and species to go extinct (Lehtinen et al. 1999; Kiesecker et al. 2001; Muths et al. 2003; Semlitsch 2003; Pounds et al. 2006; Graeter et al. 2013). Within GULN parks, there are currently no data available to assess how amphibians are responding to these stressors, when and if these stressors are present. This protocol is designed to help establish the links between amphibian population shifts and the stressors that may drive them, outlined in Table 1.

Table 1. Factors affecting amphibians within Gulf Coast Network parks and potential measures for Vital Signs monitoring. *Asterisks indicate variables that are included in GULN amphibian monitoring. The remaining listed measures are addressed through other monitoring initiatives by NPS or partners.

Stressor Category	Issue for the Park	Potential Measures
Habitat fragmentation, habitat loss and habitat change due to natural and anthropogenic effects	Roads and trails increase habitat fragmentation by blocking seasonal faunal movement and limiting genetic exchange among populations. Changes in water movement into wetlands, streams or canals can reduce available habitat for some amphibians. Conversion of one habitat type to another can reduce available habitat as well, and this may occur following extreme weather events, fire, or human activities. Outside of GULN parks, the expansion of residential/commercial properties, industry and transportation infrastructure can turn parks into relict habitat islands. Property development can also introduce invasive species, amphibians or otherwise.	Amphibian species detection over time (native and invasive)*, species richness*, and relative abundance of common amphibian species*; GULN monitoring of canopy closure and changes in plant species coverage in long-term plots; GULN LiDAR sampling to measure mid-story height and density; GULN Adjacent Land Use monitoring that tracks changes in local and regional development

Table 1 (continued). Factors affecting amphibians within Gulf Coast Network parks and potential measures for Vital Signs monitoring. *Asterisks indicate variables that are included in GULN amphibian monitoring. The remaining listed measures are addressed through other monitoring initiatives by NPS or partners.

Stressor Category	Issue for the Park	Potential Measures
Invasive species	Exotic and invasive species, amphibian or otherwise, enter parks across all boundaries and can displace native species and communities. Invasive plant species can reduce habitat quality for some amphibians (e.g., Maerz et al. 2005), as may some invasive animals, such as feral hogs and armadillos, causing damage to vernal pools. Non-native amphibians may be introduced during plantings on the park or arrive through adjacent agricultural and urban lands.	Amphibian species detection over time (native and invasive)*; relative abundance of common amphibian species*; GULN monitoring of changes in plant species coverage (native and invasive) in long-term plots
Environmental contaminants	Whether the contaminants are released on or off parks, they can still reach park fauna via water and wind. All GULN parks are downstream from urban, agricultural, and industrial sources of chemical contaminants. Within some GULN parks, there also exist old landfills, industrial sites and military-use sites that are largely unevaluated for potential contaminants. Contaminants that are known to harm adult amphibians and/or their larvae include acid rain, dissolved heavy metals (Unrine et al. 2004; Unrine et al. 2005); and insecticides (Metts et al. 2005). For many potential contaminants, their effects on amphibians are unknown and will be particularly hard to detect when they are sub-lethal (Graeter et al. 2013).	Amphibian species detection*, relative abundance of common amphibian species*, GULN water-quality monitoring, USGS hydrological projects/studies.

Table 1 (continued). Factors affecting amphibians within Gulf Coast Network parks and potential measures for Vital Signs monitoring. *Asterisks indicate variables that are included in GULN amphibian monitoring. The remaining listed measures are addressed through other monitoring initiatives by NPS or partners.

Stressor Category	Issue for the Park	Potential Measures
Disease and parasitism	Chytrid (<i>Batrachochytrium dendrobatidis</i> or <i>B. salamandrivorans</i>) fungus infects southeastern United States amphibian populations (Daszak et al. 2003; Grant et al. 2016) as does the iridovirus (<i>Ranavirus</i> sp.; Jancovich et al. 1997). These epizootic pathogens generally occur in disturbed habitats, can be transported on clothing or sampling gear, and have resulted in local population declines (Carey et al. 2003). <i>Batrachochytrium salamandrivorans</i> is known to be lethal to at least one GULN species (<i>Notophthalmus viridescens</i> ; Figure 2; Martel et al. 2014)	Amphibian species detection*, relative abundance of common amphibian species*, USGS amphibian monitoring and disease tracking studies. The GULN protocol narrative and SOPs do not include specific methods for detecting pathogens, but they do reference publications on how to document a mortality event or if diseased amphibians are found (e.g., Duffus et al. 2017; Gray et al. 2017). The GULN protocol also includes methods for preventing inter-population dispersion of pathogens and parasites during monitoring.
Collection, harvest and road kill	Amphibians are removed from the environment as pets, as a food source/bait, and for biological supply companies. This removal can be unsustainably high and result in species declines (Jenson and Camp 2003). For some amphibian species, direct mortality due to roads is also a serious problem (Fahrig et al. 1995; Forman et al. 1998). Road-side specimen collection and road-kill may selectively remove individuals seeking mates or adults dispersing to other habitats.	Amphibian species detection*, relative abundance of common amphibian species*, night-time or calling surveys by NGOs, USGS and the public. Observations of amphibians crossing roads at night; law enforcement detecting illegal frog hunting on parks.



Figure 2. The eastern newt (*Notophthalmus viridescens*) is known to be susceptible to a harmful chytrid fungus only recently documented in the United States. This species is on the amphibian checklist for both Gulf Islands NS and Jean Lafitte NHP&P, where it used the network's coverboards during the project's pilot phase.

Amphibian Resources in Gulf Coast Network Parks

Each park differs in the number of known amphibian species, and even within parks, the assemblages vary among habitats. Species checklists are available for each park, based on reptile and amphibian inventory projects prior to 2009 (see Appendix B). During pilot data collection, a few new species were detected by the Gulf Coast Network, as described below. Because the network uses only a subset of capture methods, however, few additional new records are expected relative to intensive inventory efforts.

Gulf Islands National Seashore (GUIS): The most recent amphibian inventory at Gulf Islands NS was performed in 2004–2006 (Mohrman and Qualls 2008). This work produced a checklist of twenty-six amphibian species, nineteen of which were detected during their field work. Of the seven species that were undetected in 2004–2006, five had been found during earlier surveys in 1992–1997 (Seigel and Doody 1996; Seigel et al. 1997) and two were museum vouchers from the 1950s at Davis Bayou. Twenty of the twenty-six species on the checklist are known to occur in the Naval Live Oaks Area, eighteen are in Davis Bayou, eight are in the Fort Pickens Area, five are on Horn Island, five

are on Perdido Key, four are on East Ship Island, three are on Petit Bois Island, and one is on West Ship Island.

Among the twenty-six amphibian species at Gulf Islands NS, two are of special conservation concern and one is of concern as a non-native species. The two species of conservation concern are known from decades-old observations, and neither has been seen recently in the park. The pine barrens treefrog, *Hyla andersonii*, was recorded by Seigel et al. (1997) near Fort Pickens, likely during a calling survey. This species was a “species of special concern” in Florida until 2016, when it was unlisted because its status was deemed stable (Florida Fish and Wildlife Conservation Commission 2016). The mud salamander, *Pseudotriton montanus*, was documented in 1957 in Davis Bayou, but has not been recorded there since. This species is currently listed in Mississippi as “imperiled to rare or uncommon” (Mohrman and Qualls 2008). The non-native greenhouse frog, *Eleutherodactylus planirostris* (Figure 3), was detected in the Naval Live Oaks Area in 1997 by Seigel et al. (1997), in 2004 by Mohrman and Qualls (2008) and throughout pilot data collection by the Gulf Coast Network (2011–2017). This species is native to islands in the Caribbean, and its earliest sighting in the United States was in southern Florida in late 1800s (Dorcas and Gibbons 2008).



Figure 3. The greenhouse frog (*Eleutherodactylus planirostris*) is an exotic amphibian found in sections of both Gulf Islands NS and Jean Lafitte NHP&P.

Jean Lafitte National Historical Park and Preserve (JELA): Anderson and Seigel (2003) performed the most recent inventory of amphibians at Jean Lafitte NHP&P, with data collection from 2001–2002. During their field sampling, they detected sixteen amphibian species across the Barataria Preserve. They reported two additional species from a previous study (Rossman and Demastes 1989), and they include one more based on its habitat preferences, distribution map, and nearby collections.

The Gulf Coast Network added one more species to this list during their pilot data collection conducted between 2011 and 2017, bringing the total species count to twenty. Jean Lafitte NHP&P-Barataria has the longest record of herpetological monitoring by the network because it was used for primary methods development.

There are no rare or threatened amphibians documented within the Barataria Preserve boundaries, but there are two non-native species of concern. The same non-native greenhouse frog (*E. planirostris*) that occurs in Gulf Islands NS is also documented in Jean Lafitte NHP&P (Figure 3). Anderson and Seigel (2003) recorded this species outside the JELA park boundary in 2001–2002. The network detected it for the first time in September 2012 near the education center and continues to record it there regularly. The Cuban treefrog (*Osteopilus septentrionalis*) is also considered a potential invasive threat in southern Louisiana, although as of 2018 there is only one known established population in the state. This breeding population was recently documented at Audubon Park in New Orleans by Glorioso et al. (2018), with the progenitors likely to have arrived on plant nursery shipments from Florida. Control measures have been taken on that population, which is 15 kilometers (9.3 miles [mi]) from Jean Lafitte NHP&P on the other side of the Mississippi River. If introduced to the national park, this species would be likely to harm native treefrog populations (Powell et al. 2016).

San Antonio Missions National Historical Park (SAAN): Duran (2004) conducted the most recent amphibian inventory at San Antonio Missions NHP and detected seven amphibian species in the park. The Gulf Coast Network conducted pilot work from 2011–2017 at the main Missions properties and from 2011–2014 at the Rancho de las Cabras property, which is 64.4 kilometers (40 mi) south of San Antonio. This work brought the total count to nine, although two of the nine are recorded at the Rancho property but not at the Missions.

There are no species of conservation concern known within the boundaries of San Antonio Missions NHP, but there is one species that is non-native to the San Antonio area. *Eleutherodactylus cystignathoides* (Figure 4) is native to Mexico, with an indigenous U.S. population in the Rio Grande valley adjacent to Brownsville, Texas. This species is expanding around the Gulf Coast, and now appears as far east as Lafayette, Louisiana. A population has been detected at urban sites in San Antonio Missions NHP, where it may become useful as a potential indicator of system-change.



Figure 4. The Rio Grande chirping frog, *Eleutherodactylus cystignathoides*.

Measurable Objectives and Thresholds

The network has two measurable objectives for monitoring amphibians in Jean Lafitte NHP&P, Gulf Islands NS, and San Antonio Missions NHP. Because the network selected specific sites within each park for monitoring, this protocol's objectives and results apply only to the focal areas and cannot provide park-wide inference. The specific objectives are:

- Determine species composition of the amphibian communities that use the monitored cover objects (PVC pipes and coverboards) at each site, and determine species richness for native and exotic species separately.
- Determine the frequency (yes/no detected) and relative abundance (counts per pipe or board) of the more commonly encountered amphibian species at each site, and determine trends over time.

By collecting and reporting on data as prescribed by these objectives, the Gulf Coast Network can provide the regular updates and management recommendations that are essential for informed and effective resource management in parks. At two- and six-year intervals, the network summarizes and analyzes data to assess whether the resource condition appears stable and whether any specific actions are advisable, management or otherwise. Thresholds for recommending further research or specific actions by the park include –but are not limited to– (1) field observations of extraordinary and concerning events (e.g., a new and harmful invasive species or a major mortality event), (2) a species that was previously fairly common going undetected for four or more years, or (3) analyses that reveal a statistically significant increase or decrease in the frequency or relative abundance in one of the network's targeted amphibian species. When one such trigger point is met, the network informs the park and other interested stakeholders with direct communications, a short memo, or for trend analyses, a longer report that provides ecological context and interpretation through literature review or consultation with experts.

Sampling Design

Arrangement of Artificial Cover Objects within Sites

GULN Design: The Gulf Coast Network arranges its artificial cover objects in fixed, permanent locations along transects. At the two larger parks, Gulf Islands NS and Jean Lafitte NHP&P, there are two transects per park, roughly 140 meters (459 feet [ft]) long and separated by a distance of greater than or equal to 1 kilometer (.6 mi). In these parks, the transects follow a single elevation band that is adjacent to a permanent to frequently flooded, fresh waterbody. In some instances, the elevation band is relatively straight, but in others, it is curved. In the third park, which has less available habitat, there are three shorter transects of 80 meter (328 ft) lengths, but they are still greater than 1 kilometer (.6 mi) apart and near fresh waterbodies. Each site's specific layout is illustrated in Appendix A.

At 20–30 meter (65.6–98.4 ft) intervals along each transect, there are up to eight clusters of four plywood coverboards, with each coverboard 0.9×1.2 meters (3×4 ft) in size (Figure 5). The four coverboards are placed flat on the ground, all within 1–2 meters (3.2–6.5 ft) of each other. At the two larger parks, there are 16 clusters divided evenly between the two transects, and each cluster is accompanied by six PVC pipes painted dark brown and hung in pairs on the three closest hardwood trees at a height of 1.37 meters (4.5 ft). Each pair consists of a smaller pipe and a larger pipe (see “Field Methods” section for more details). Within 40 meters (131.2 ft) of each transect, there are up to eight more pairs of PVC pipes hung on trees in or along standing water (Figure 5). No PVC pipes are used at San Antonio Missions NHP, due to their ineffectiveness at attracting treefrogs during the pilot study (for details, see Carlson [2018]). San Antonio Missions NHP also has only five clusters of coverboards, rather than eight, due to space limitations in the smaller park.

Justification: Artificial cover objects are deployed in groups along a transect because this arrangement is well suited for sampling at permanent locations over long periods of time (e.g., Heyer et al. 1994; Dodd 2003; Graeter et al. 2013). The approach of clustering coverboards along a transect specifically follows the example in Dodd (2003) for amphibian monitoring in the Great Smoky Mountains, with two primary differences. One difference is that GULN boards are larger, at 91×122 centimeters (3×4 ft) rather than 20×25 centimeters (7.8×9.8 in) or 35×35 centimeters (13.7×13.7 in). The larger size was selected because it was successful during amphibian and reptile inventories in GULN parks (Anderson and Seigel 2003) and there was interest in maintaining some consistency in the chosen techniques. The second difference is that GULN clusters are placed farther apart, with 20-plus meters between clusters, rather than 10 meters between clusters, to accommodate the larger board size.

Placing boards and pipes in clusters along transects was considered a better option than selecting locations at random or along a grid within a target area. There are three main reasons why this approach was preferred: (1) the transect arrangement systematically covers a relatively long distance; (2) transects are a logistically practical way of keeping track of boards and pipes; and (3) using transects allowed for improved selection of replicate sites within Gulf Islands NS and Jean Lafitte NHP&P. For these two parks, the Gulf Coast Network required that replicate sites within parks followed the same elevation band within a particular habitat type, so that they were more likely to

represent similar types and availability of resources for amphibians. At San Antonio Missions NHP&P, it was not possible to place the three transects (of five clusters each) along a single elevation band because available habitats were too small. For that park, the only requirement was that transects were in forested habitats and within 50 meters (164 ft) of a waterbody.

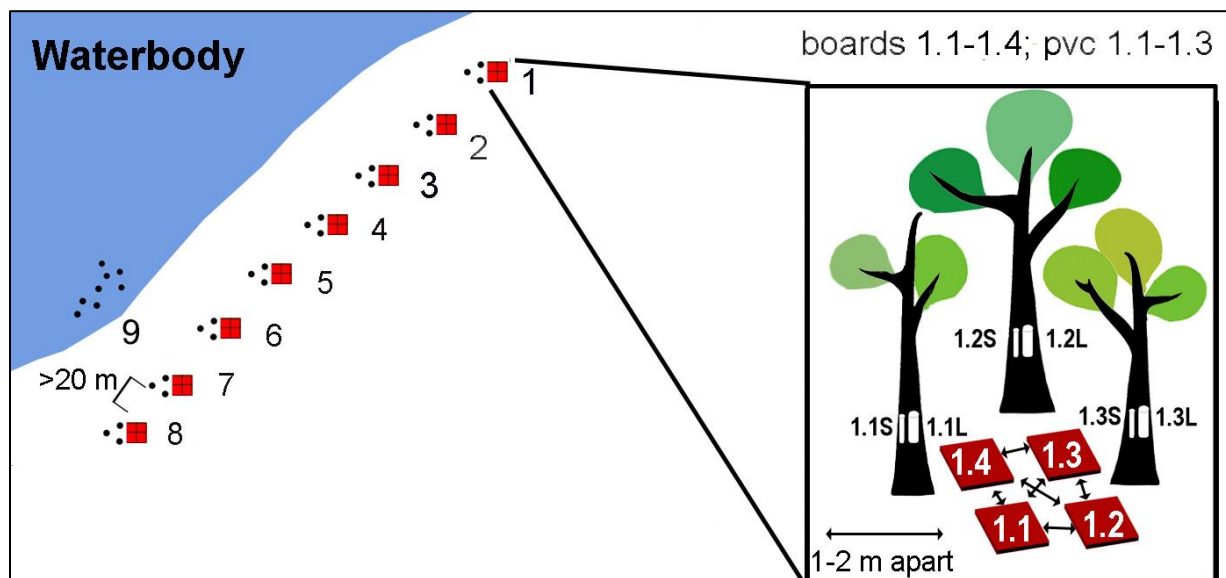


Figure 5. Diagrammatic arrangement of PVC pipes and coverboards in two of the three GULN amphibian monitoring sites (Jean Lafitte NHP&P and Gulf Islands NS). In the main diagram, each black dot is a pair of pipes, one small (S) and one large (L); see text for details. Each red square is a plywood coverboard. All boards and pipes are grouped into eight clusters (1-8) along a transect, except for group 9, which is 8 pairs of pipes in trees that are in the nearest waterbody. The transect follows a single elevation band, which is matched for the replicate site within a park. The black inset box is a diagram of how the boards and pipes are placed within a cluster. The two white cylinders on each tree trunk represent the pair of PVC pipes, labeled S and L. The layout of the third GULN amphibian monitoring site (San Antonio Missions NHP) is similar, except that no PVC pipes are used, and there are five, rather than eight clusters per transect.

The Gulf Coast Network added an extra set of PVC pipes over water based on evidence from the pilot data set. In both Gulf Islands NS and Jean Lafitte NHP&P, pipes hung over water were occupied by the green treefrog, *Hyla cinerea*, more often than pipes hung over land, and the inverse was true for the squirrel treefrog, *Hyla squirella* (see Carlson [2018] for more details).

The PVC pipes and coverboards are co-located in clusters primarily for ease of sampling, but they also provide the opportunity to assess cluster-level effects across the two types of cover objects. In most cases, the local conditions affecting pipe occupancy are not likely to influence coverboard occupancy, but there may be larger-scale stressors that could be assessed with correlative data. For example, if the canopy opened over a cluster following tree defoliation or death, both the boards and the pipes may house fewer amphibians because of increased solar radiation leading to temperature increases and desiccation.

Site Selection and Within-Park Replication

GULN Design: The Gulf Coast Network's sampling frame for amphibian monitoring is selected to focus on specific habitats and areas, as identified by park management. The sampling frame is not intended for making park-wide inferences. Each park-selected site does have at least one replicate site within the same park, however, which is at least 1 kilometer (0.62 mi) away. In most cases, these replicate sites were added after the project's pilot phase, to help achieve sufficient statistical power for detecting trends in the focal habitats. For Gulf Islands NS, the network monitors amphibians at two pine/oak forest/scrub sites on the Naval Live Oaks Area. For Jean Lafitte NHP&P, monitoring takes place at two sites in the Barataria preserve, both within less-flooded bottomland hardwoods habitats. For San Antonio Missions NHP, the network monitors amphibians on three forested sites within the main San Antonio property, but not at Rancho de las Cabras. See Appendix A for study site locations for all three parks.

The seven focal sites across the three parks were selected through a several-step process:

- Park resource management identified sites that were likely to house viable amphibian populations and were of management interest.
- The GULN team determined if those sites were suitable for pilot monitoring work, in that:
 - They were relatively dry and easy to access on foot;
 - They were in locations where coverboards and pipes would not be immediately visible to the public; and
 - They had some trees and an adjacent waterbody.
- Six-plus years of pilot data were collected and analyzed for those sites.
- Based on power analysis results, the GULN team added replicate sites in two parks, which were selected to have similar elevations and habitat characteristics as the existing sites. The GULN also removed one less-productive site from the third park (San Antonio Missions NHP), so that more effort could be invested in its three more-productive sites. Additional details on the site-selection process are provided in Appendix A.

Justification: The sampling frame and sampling points reflect the constraints imposed by:

1. The well-documented habitat-specificity of most amphibian species where population are concentrated in small patches of better habitat (Heyer et al. 1994);
2. The evident local and patchy nature of most key habitat types in GULN parks, i.e., forest adjacent to a fresh waterbody;
3. The recognized need for parks to focus on selected resource units to maintain program efficiency and effectiveness; and
4. Limitations on GULN time and resources, such that each park must be sampled in a single morning or two consecutive mornings, keeping park-wide sample sizes to 60 coverboards

across three sites at San Antonio Missions NHP and 64 coverboards and 128 pipes across two sites at each of Jean Lafitte NHP&P and Gulf Islands NS.

The Gulf Coast Network considered several scales and intensities for sampling before deciding to limit its scope to artificial cover objects in a small number of sites. A broader-scale alternative is presented by the Amphibian and Reptile Monitoring Initiative (ARMI 2017) with its core, or mid-level approach to data collection. The core ARMI program monitors species presence and distribution at many locations across large geographic scales, with a sampling design that allows for region-wide inference (Corn et al. 2005). The ARMI's broad sampling frame is often balanced by sampling less frequently (often with visual encounter surveys or acoustic monitoring) and not using artificial cover objects visited repeatedly over time. The regional focus results in the ARMI approach providing limited information on populations and assemblages at local land-management scales.

The GULN amphibian monitoring also differs in scope from earlier inventories performed in each of the parks. For example, the amphibian monitoring performed at Gulf Islands NS—Davis Bayou (Mohrman and Qualls 2008) sampled more than 18 locations across the unit. The objective was to detect as many species as possible, and the effort was distributed across many habitats that each employed a different suite of methods. Although this approach worked well for the inventories and has helped guide the network's site selection, using many capture techniques each time requires more set-up time and larger sample sizes than is logistically feasible for long-term monitoring by the network.

Unlike the above two examples, the Gulf Coast Network designed its sampling frame to meet small-scale resource management needs with locally-intensive, repeatable sampling in target habitats over the long-term. The network selected only two sampling methods across the three parks and chose only one habitat type per park. This approach allows for sufficient data to be collected on the species that commonly used monitored pipes and boards in those sites, such that the relative abundance can be assessed. The trade-off is that many of the species known to the parks are not monitored through this protocol, and several parks are not monitored at all because the selected methods were not initially successful. Long-term, community-wide monitoring of amphibians in all GULN parks may need to be addressed through other means, potentially resembling the alternative, inventory-like approaches described above. These taxonomically-broad efforts would happen less frequently (once every three to five years) and would require intensive effort over a short amount of time.

Targeted and Detected Amphibian Species

The network approach provides long-term data on the composition of amphibian assemblages using PVC pipes and coverboards and on the relative abundance of a few most-common species. During pilot data collection, at least 50% of each unit's known species were detected in the artificial cover objects. This subset differed slightly among parks, in part because the geographic ranges of the species are different and because some species behave differently in different habitats. The numbers of detected and common species for each sampling unit are listed below.

Gulf Islands NS: There are twenty amphibian species known to the Naval Live Oaks Area, which are listed in Appendix B. Based on pilot data collected by the network, only ten of these species are

known to use the artificial cover objects employed in this protocol. Further, only four of the ten may be abundant enough to monitor for relative abundance over time: squirrel treefrog (*H. squirella*), pine woods treefrog (*H. femoralis*), green treefrog (*H. cinerea*) and greenhouse frog (*E. planirostris*).

Jean Lafitte NHP&P: Inventory and pilot work revealed nineteen amphibian species within the Barataria Preserve at Jean Lafitte NHP&P, with one additional species presumed in the park but not yet recorded there. Of these species, eleven are known to use the artificial cover objects employed in this protocol (see Appendix B). Six of the eleven may be abundant enough to be monitored for relative abundance over time: squirrel treefrog (*H. squirella*), bird-voiced treefrog (*Hyla avivoca*), green treefrog (*H. cinerea*), Gulf Coast toad (*Incilius nebulifer*), narrow-mouthed toad (*Gastrophryne carolinensis*) and greenhouse frog (*E. planirostris*).

San Antonio Missions NHP: Pilot work at four forested sites within the San Antonio Missions NHP demonstrated that five amphibian species use the GULN cover objects. There are two additional species known to that section of the park that were not detected during GULN pilot monitoring (see Appendix B). Of the five species using GULN cover objects, only two are common enough to monitor changes in relative abundance over time: Gulf Coast toad (*I. nebulifer*) and Rio Grande chirping frog (*E. cystignatoides*).

Because the GULN approach is designed for locally abundant species, it will generally be ineffective for monitoring rare or specially-protected species. Monitoring and detecting rare or hard-to-find species is a complex and difficult process, which can require specialized designs, methods, and analyses (Thompson 2004; McComb et al. 2010; Graeter et al. 2013). Even so, GULN amphibian monitoring may occasionally yield rare or previously unreported taxa, and this can contribute to park species checklists.

Sampling Frequency and Timing

GULN Design: Within each park, all coverboards and PVC pipes are checked during a single morning or two consecutive mornings (between sunrise and noon) once every other month. If on the same morning, the two or three sites per park are always sampled in the same order on that morning, as are the PVC pipes and coverboards within sites. Use of a standard sampling order provides a rigorous and consistent temporal frame and data structure over time and for all parks. The order is probably not particularly important within a site, given that 30 boards and 52 PVC pipes used in the JELA pilot study were typically checked in less than 1.5 hours. Time-order effects may, however, be significant among sites. It must be noted that if the two or three sites are sampled in the same morning, there is a tradeoff for sampling in the same order each time: the 2-hour sampling block is confounded with the site itself.

Each park is generally sampled during the same week of the month, with Jean Lafitte NHP&P and Gulf Islands NS sampled in the same month, and San Antonio Missions NHP sampled in the alternate month (Table 2). Within each month, it is possible to move park sampling ahead one week to accommodate network and park staff needs or to avoid anticipated severe weather (e.g., hurricanes or severe weather fronts).

Table 2. Sampling schedule for the three parks that GULN monitors for amphibians. An X indicates that sampling takes place in that month.

Park and Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Gulf Islands NS (3d week of month)	X	–	X	–	X	–	X	–	X	–	X	–
Jean Lafitte NHP&P (4th week of month)	X	–	X	–	X	–	X	–	X	–	X	–
San Antonio Missions NHP (2nd week of month)	–	X	–	X	–	X	–	X	–	X	–	X

Justification: Pipes and boards must be checked before noon because that is when detection rates should be highest. Many amphibian species are sensitive to thermal conditions and will leave artificial cover objects as they become too hot in the afternoon (Heyer et al. 1994; Graeter et al. 2013). Network pilot work shows all sites within a park can be completed before noon in a single morning, but if not, a second day of field work is required.

Sampling in parks is designed to span the entire year, to capture fluctuations in relative abundance and presence of different amphibian species. For example, the peak detection season for Hyliid treefrogs in Jean Lafitte NHP&P is winter (November–March) when these frogs appear more frequently in PVC pipes. *Incilius nebulifer* and *Eleutherodactylus planirostris* at Jean Lafitte, in contrast, seem to inhabit coverboards throughout the year. During the project’s pilot phase, sampling took place once per month, but subsequent power analyses suggested that every-other-month sampling provided comparable power to detect trends (for details, see Carlson 2018).

Power Analysis

The Gulf Coast Network has two reports available that discuss the network’s power to detect trends, both using five years of pilot data (Cheng 2016; Cheng 2017; both unpublished reports available online). The first report is a preliminary analysis of the status and trends in species richness and species diversity. The second report is a power analysis on abundance data from nine common species.

The following two questions were addressed in the first report:

- Did amphibian diversity and richness change significantly from 2011 to 2015?
- Can diversity and richness be estimated reliably through the GULN approach?

The report concludes there were no linear trends in the pilot data set; however, five years of data were too few for reliable trend detection in amphibians. Even over longer timespans, the report writers conclude that trend detection will be limited due to low capture rates. Further, the report provides evidence that a reduction in sampling frequency would have negative consequences for the quality of diversity and richness estimates. The network’s interpretation and responses to this report are provided in a supplemental information report, available online (Carlson 2018).

The following three questions were addressed in the second report:

- Is the GULN's pilot sampling effort sufficient to allow for detection of trends in relative abundance of nine common species over five or ten years?
- Could sampling be reduced from monthly to alternate months without losing statistical power?
- If the number of artificial cover objects was increased by 50% per site, would this improve trend detection?

This second report concludes that the Gulf Coast Network will not have the power to detect fairly large increases or decreases in relative abundance if they continue with the same sample sizes and sampling frequencies as the pilot study. Specifically, under the pilot design, there is insufficient power to detect a net increase or decrease of up to 54% of the starting relative abundance values for a given species over 10 years in any park. However, given that sampling every-other-month provides equivalent power as the current monthly sampling regime, the network could potentially shift effort to alternate months. The Gulf Coast Network should also measure more covariates and sample more sites per park. As with the first report, the network's interpretation and responses for the second report are provided in the supplemental information report, Carlson (2018).

Based on these results and a modified sampling design, the Gulf Coast Network has set fairly conservative statistical targets for being able to detect real trends over time. As stated previously, the protocol aims to monitor change over time in the common species found in PVC pipes or under coverboards using occupancy (proportion of pipes or boards occupied) and relative abundance (counts per pipe or board). For the proportion occupied per park, the Gulf Coast Network sets the target for minimum change detection at 50% over a twelve-year period. For relative abundance, the target is also set at detecting a minimum increase or decrease of 50% in the number of individuals per pipe or board of the most common species (expecting three or fewer such species per park). In both cases, the target for statistical power is 80%, and the alpha level is 0.10. A twelve-year period is used because this represents two full reporting intervals for amphibian monitoring by the Gulf Coast Network.

Field Methods

PVC Pipes and Coverboards as Artificial Cover Objects

GULN Design: The Gulf Coast Network monitors amphibians using two types of artificial cover objects: plywood coverboards placed flat on the ground (Figure 6) and PVC pipes hung from trees (Figure 7). The coverboards are made of 1.3 centimeters (0.5 in) thick plywood, with a single piece cut to make two boards sized 1.2×0.9 meters (4×3 ft). The PVC pipes are 0.61 meters (2 ft) long with a cap on the bottom and a rope passing through, to allow small mammals to climb out (see Borg et al. 2004 for original design, or see Woodman et al. 2018a for the GULN-specific design). Two different-sized pipes (2.5 centimeters [1 in] and 5 centimeters [2 in]) are hung in a pair from the same tree with the pipe openings at 1.37 meters (4.5 ft) above ground level. Pine trees are to be avoided. The trees must be greater than 10 centimeters (3.9 in) diameter at breast height (DBH), unless no living trees of that size are available. In all cases, tree species identity and DBH are recorded for inclusion as covariates in statistical models.

All pipes and boards in a site are checked once every other month by a crew of two people. The pipes can be checked by a single person, with the other person recording data. To check the boards, however, both team members are required. See the “Sampling Methods” section for more details. The boards and pipes require little or no maintenance over time, but when initially deployed, replaced or moved, both require one month of “settling in” prior to the next sampling (Dodd 2003).



Figure 6. Non-toxic plywood coverboards at San Antonio Missions NHP. Coverboard dimensions are 0.9 x 1.2 meters.



Figure 7. Pair of PVC pipes at Gulf Islands NS. One pipe in the pair is 2.5 cm [1-inch] in diameter and the other is 5 cm [2 inches] in diameter. All pipes are painted brown-grey for camouflage and to help standardize internal conditions, although paint may become slightly scratched and worn over time.

Justification: PVC pipes and plywood coverboards are commonly used as artificial cover objects in amphibian inventory and monitoring projects (Dodd 2003, 2010; Mohrman and Qualls 2008; Graeter et al. 2013). The advantages are they are easy to check, inexpensive, can be left without regular maintenance, and allow animals to come and go unharmed. They are also generally safe to use for sampling personnel, and because they are widely used, their expected yields (and performance shortfalls) are well understood. These characteristics address both park concerns about faunal resource effects and potential danger to personnel, and they support program efficiency by limiting equipment costs and time in the field. The limitations are that not all amphibian species will use them (see “Targeted and Detected Amphibian Species” above), and some species may use them more often others, resulting in interspecific capture bias (Dodd 2003; Zacharow et al. 2003; Hoffmann et al. 2009; Glorioso and Waddle 2014). As a result, these methods provide data on the presence, but not the absence of a given species, and they can indicate relative abundance of a species over time (i.e., counts per cover object compared one time to the next, for that species in the same site), but they do not indicate true abundance in the site (Dodd 2003).

Despite their limitations, these two types of artificial cover objects were used often enough by one or more amphibian species per park during the GULN pilot study (2008–2017) to warrant their continued use in long-term monitoring (see Cheng 2016, Cheng 2017 and Carlson 2018). The pilot data were also employed to make final decisions on the material specifications of artificial cover objects for long-term monitoring. For example, the network decided to include both pipe sizes because the smaller pipe size contained squirrel treefrogs more often than did the larger pipe size, and the larger pipe size contained green treefrogs more often. In a contrasting example, the pilot data showed that deploying 50% plywood and 50% tin coverboards was disadvantageous, relative to deploying 100% plywood boards. This was because the tin boards were less frequently occupied by any of the board-using amphibian species across all times of year. For this reason, only plywood boards are used during the long-term effort. The supplemental information report by Carlson (2018) provides more details on these pilot data comparisons.

Other sampling techniques were tested in Gulf Islands NS and Jean Lafitte NHP&P prior to or during the pilot phase (i.e., Seigel and Doody 1996; Anderson and Seigel 2003; Mohrman and Qualls 2008). These included time-constrained visual ground searches, calling surveys, drift fences with pitfall traps or funnel traps, and minnow traps.

The two chosen methods were preferred to the others because:

1. Visual ground searches are difficult to standardize across users and sites, and based on GULN pilot work, they are extremely variable in their success rates;
2. Drift fences and traps must be checked several times a day to avoid harming animals and must be set-up each time or maintained;
3. Based on pilot work, minnow traps produce too few captures to justify the effort required (Carlson 2018); and
4. Calling surveys require night-time visits, can be difficult to time, and can be highly seasonal or weather dependent.

The alternative of installing recording equipment was considered, but this approach was not preferred, because these recordings could only indicate detection/non detection and not relative abundance.

Cover object-level and Site-level Covariates

GULN Design: The Gulf Coast Network collects data on several environmental covariates in association with each sampling event. At the level of individual pipes or boards, three variables are recorded. First, the crew member records the presence or absence of sunlight directly on the pipe or board. Second, the crew member records surface temperature under the board or inside the PVC pipe using a hand-held infrared thermometer. Third, the crew member records the presence or absence of flood water at a coverboard location and the presence or absence of obstructive occupants in PVC pipes. At the level of a transect site (all 32 boards and 64 pipes per site for JELA and GUIS, or 20 boards per site for SAAN), a crew member records the time, weather condition, air temperature and

relative humidity at the start and end of sampling. For details on how these data are collected as part of a field sampling trip, see GULN SOP AM03—*Field Methods for Amphibian Monitoring* (Carlson et al. 2018a). Also at the site level, the network deploys and maintains continuous data loggers that are located near the mid-point of the transect. One data logger records temperature and relative humidity every hour, and the other collects hourly data on barometric pressure. Finally, the network deploys a continuous water-level logger in the nearest waterbody to each site. Instructions on the deployment and use of these loggers are in the GULN internal document *Deployment of and Data Extraction from Continuous Data Loggers* (Woodman et al. 2018b).

The Gulf Coast Network acquires additional covariate data from nationally-available climate and weather databases. Daily rainfall and temperature data come from the nearest weather station to each site, which is less than 2 kilometers (1.2 mi) away at Jean Lafitte NHP&P, less than 3 kilometers (1.8 mi) away at San Antonio Missions NHP, and 12 kilometers (7.4 mi) away at Gulf Islands NS. These data are used to assess temperature and rainfall during the week prior to sampling as well as to create longer-term averages that may help explain fluctuations in amphibian abundance across seasons or years. Additional information for how these data are obtained and managed is provided in SOP AM03 and SOP AM06—*Data Management* (Granger et al. 2018a).

Justification: The Gulf Coast Network measures covariates at each artificial cover object and each site or visit as a means of explaining variation in amphibian captures over time. Adding covariate data was recommended by Dodd (2003) for the Great Smoky Mountains, with specific mention of air temperature, substrate temperature, relative humidity, rainfall and barometric pressure data. Measuring a wide range of covariates was also recommended in the power analysis report for GULN pilot data, as mentioned above (Cheng 2017). This component of the project should improve statistical power for trend analysis of amphibian abundance over time.

Field Schedule and Preparations

Each park is sampled during one or two consecutive mornings on alternate months, and as such, advance preparation is essential. The SOP AM02—*Preparation for Sampling and Equipment List* (Carlson et al. 2018b) describes the required preparations and equipment needed for fieldwork. The field crew must have at least two members: the crew leader and the data recorder. The crew leader is responsible for preparing field equipment and supplies, leading field activities, functioning as the safety officer, and training the data recorder as necessary. At least two weeks prior to the trip, the crew leader ensures permission and participation (when needed) from the park person of contact (POC), who is typically the resource manager for that park. Just prior to the trip, the crew leader assembles the necessary field equipment and prints the data sheets. They also write down which of the 18 clusters (or 15 for San Antonio Missions) will be used for quality control on species identification (details in “Sampling Methods” below) for that park visit. Finally, they confirm availability of the park’s POC and the network’s POC, whom the field crew leader contacts at the start and end of the field day as a safety measure. See SOP AM01—*Safety* (Carlson et al. 2018c) for more information about how the network prepares for and maintains safe working conditions in the field.

Permitting and Compliance

Once per year, or less frequently depending on the park, the Gulf Coast Network reviews and renews its park research permits for amphibian monitoring fieldwork. Permit documents are updated and submitted to the park by the protocol lead at least two months prior to the expiry of the existing permit. The protocol lead also communicates directly with the park POC regarding any changes or new additions to sampling practices that may need to be described in the permit. For each sampling event, the field crew maintains a copy of the current research permit in the field vehicle and follows any other practices stipulated in the park's permit. Prior to implementation, a description of this project was submitted to the National Park Service Institutional Animal Care and Use Committee (NPS IACUC). It was decided that the project classified as a 'field study', such that IACUC review and permits are not required.

Sampling Methods

The roles and procedures for field sampling are detailed in SOP AM03. In brief, the data recorder and crew leader begin sampling in the park as soon as possible after sunrise. The crew always begins with the same site, and they sample the clusters within that site in the same order each time. Prior to sampling, the crew leader confirms which cluster has been randomly-selected for quality control (QC) on species identifications. Only one cluster is selected per park visit, and its number must be written in the comments section of the appropriate site-level data sheet prior to departing for fieldwork. At that QC cluster, sampling proceeds as normal, except that every animal found in a coverboard or PVC pipe is photographed in a standardized set of images (see instructions below) and released. The set of QC photos is provided to a qualified GULN staff person or an outside expert for post-field ID verification.

Prior to lifting the first coverboard, the data recorder writes the following data on the site-level field sheet: start time, air temperature, relative humidity, weather, and the names of the data recorder and the crew leader. To begin sampling each cluster, the crew leader takes the cluster photopoint, which is directed toward the cluster center from the first coverboard. The team then checks the four coverboards followed by the three pairs of PVC pipes, and fills in the data sheets specific to the coverboards and pipes, respectively. As each board or pipe is checked, a crew member uses the infrared thermometer to measure the surface temperature on the ground under the coverboard or inside of the pipe. This temperature is recorded on the coverboard or pipe data sheet. The data recorder also writes down when a pipe or board is in the sun, when a board is affected by floodwater, or when there is an occupant in a PVC pipe that could deter amphibians. If the pipe or board is missing, damaged or incorrectly placed, this is also recorded. The site-level and pipe- or board-level data sheets are included in the Appendices of SOP AM03.

To check each coverboard, the two crew members stand on opposite sides of the board. The data recorder pulls the far side of the board toward them with a snake stick, and the crew leader watches the ground area being exposed. After the board is lifted to vertical, the crew leader photographs the newly exposed ground and calls out the types and numbers of amphibians present. The photograph can be reviewed later in case an amphibian escapes before it can be identified. After collecting all data and photographs, the data recorder slowly lowers the board back onto its original footprint.

To check PVC pipes, the crew leader first corks each pipe in the pair with sponge corks. The first pipe is then removed from its nail and emptied into a plastic bag with gentle shaking. The crew leader calls out the types and numbers of treefrogs present. The two pipes on the same tree are checked and rehung one immediately after the other, and then the crew moves to the next nearest pair of pipes in that cluster.

Any amphibians that cannot be identified with certainty in the field (or the amphibians for quality control IDs) are photographed using a standardized set of images. This includes photos of lateral, dorsal and ventral views, as well as others, depending on the taxonomic group. For treefrogs, an additional photo with the rear leg extended shows leg length and thigh markings (Figure 8). For toads (Bufonidae), there should be photos taken directly above the head and back to see the cranial crest, dorsal parotoid glands, and wart details seen on the dorsal skin (see Powell et al. 2016 for examples). SOP AM03 includes all taxon-specific instructions for ID verification photos. The animals are photographed at the coverboard or pipe where they were found, and they are released immediately afterward.

After the first cluster is complete, the crew moves to complete the second cluster through to the last cluster in the transect in the same manner. The crew then records the stop time, air temperature, relative humidity and weather again. Finally, the team checks the sixteen PVC pipes over standing water, which are also measured for internal surface temperature. Before departing the site, the memory cards from the continuous-data loggers are downloaded, or the data loggers are switched out for duplicates so the data can be downloaded at the lab.

Post-Sampling Activities

The activities to be completed immediately after sampling are described in SOP AM04 *Post Sampling Activities* (Carlson et al. 2018d), with more details on the data processing steps in SOP AM06. To summarize, the crew leader reviews each data sheet for realistic entries and correct spelling of Latin names in a post-field validation step. Next, the identification QC step is completed by providing a qualified expert (GULN staff or otherwise) with access to all ID photos from the randomly-selected QC cluster. They complete independent (i.e., blind to the original ID) species identifications from these photos. Their ID designations are later compared to the originals, with matches and mismatches tracked in a QC tracker spreadsheet on the GULN server. If the original fieldsheet ID is found to be incorrect, the ID on the original is changed with an explanation in the comments section. After the QC step is complete, the crew leader signs each data sheet (including the QC sheets) to produce an accepted data sheet. Once all data sheets are signed and accepted for a single park visit, they are turned over to the data manager, who scans them and uses them for data entry. The crew leader is also responsible for cleaning and disinfecting boots and other potentially contaminated field gear, stowing equipment, and downloading and storing photos and environmental data on the server.

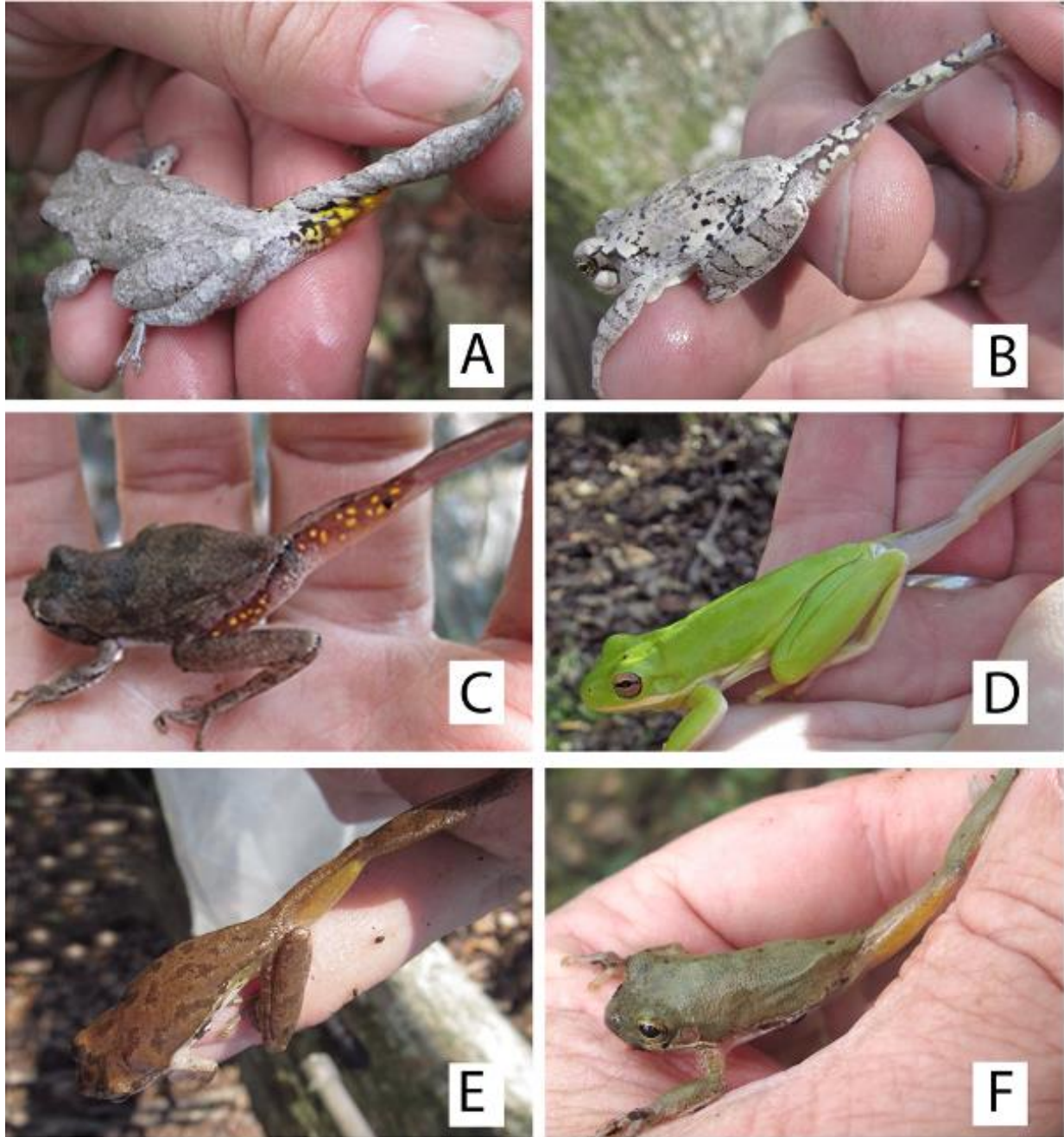


Figure 8. Treefrogs with their hind leg extended, which is a key feature for identifying the five most-likely Hylid treefrog species in Gulf Coast Network parks. (A) Members of the grey treefrog complex, *Hyla versicolor/chrysoscelis*, have a bold yellow patch with dark mottling. (B) The bird-voiced treefrog, *H. avivoca*, resembles *H. versicolor/chrysoscelis* but lacks the bold yellow patch. In some individuals, the patch is light green but never yellow. (C) The pine woods treefrog, *H. femoralis*, has small yellow spots on the femoral region. (D) The green treefrog, *H. cinerea*, has no markings in the femoral region, and the skin color is white, transparent or cream. (E) The squirrel treefrog, *H. squirella*, has no markings in the femoral region, but the skin in that region is often tinted yellow. (F) a greener squirrel treefrog with yellow femoral skin.

Data Management

Data Management and Process

A full description of this protocol's data management plan and QA/QC practices is provided in SOP AM06—*Data Management*. To summarize, the data management workflow is as follows (see also Table 3):

- **Preparation**—trip logistics are planned, supplies are assembled following equipment lists, and paper data sheets are printed (See SOP AM02—*Preparation for Sampling and Equipment List*).
- **Data acquisition**—Data are collected by the field crew on paper data sheets, in accordance with SOP AM03—*Field Methods for Amphibian Monitoring* instructions. The final products from this step are raw data sheets.
- **Data sheet review/verification**—Prior to departing the field site, the data recorder reviews the data sheet for completeness. The final products from this step are verified paper data sheets.
- **Data sheet validation and quality control on species ID**—The ecologist or crew leader (familiarity with GULN amphibians required) checks each data sheet for realistic entries and correct spelling of Latin names. An expert who was not in the field and has not yet viewed the data sheets conducts the independent quality control (QC) check of species IDs from photos taken at a randomly selected cluster for each park visit. The original data sheet is corrected if necessary. All corrections to the data sheets are initialed and made with a different color pen, with the original entry crossed out with a single line. The final products from this step are validated paper data sheets (SOP AM04—*Post- Sampling Activities* and SOP AM06).
- **Accepted data sheets**—After checking for realistic entries, making corrections and completing the identification QC step, the ecologist or crew leader signs and dates the data sheet. The sheets are then digitally scanned and stored as the final, accepted data sheet (SOP AM04).
- **Data entry, processing, and backup**—All entries that were recorded on the paper data sheets are entered into the Amphibian and Reptile monitoring database. This step is completed on computers in the GULN office. The final product of this step is a raw, entered data set (SOP AM05—*Entering Data into the Database* [Granger et al. 2018b]).
- **Database verification and quality review**—As data are entered from paper data sheets into the database, multiple verification checks are performed. First, after entering each data sheet into the database, the typist compares the database and data sheet to ensure all typed numbers match what was written. Second, a different staff member reviews all data sheets entered that day to again ensure that all typed data match the data sheet. This is the 100% check. Third, either the data manager or protocol lead reviews 10% of all data sheets, again for proper entry from the data sheet. This is the 10% check and also functions as quality review. The

final products at this stage are verified and quality-checked data in the database (SOP AM06).

- **Database validation**—After data are verified as entered correctly, additional validation tests are completed by the ecologist to ensure that data in the database are logically consistent and realistic. These steps include plotting presence and relative abundance over time and reviewing species lists. At the end of this stage, the products are validated data in the database (SOP AM06).
- **Accepted database**—After verification and validation steps are complete, the data are classified as accepted. If the Quality Assurance Plan (QAP) for the protocol is in place, the database is considered certified (SOP AM06).
- **Metadata/documentation and data delivery**—All data that are accepted or certified are accompanied by metadata that describe that dataset and document the results of the quality review. The products here are accepted data and the associated metadata, which can then be archived and uploaded to the master project database. These products should be completed within three months of a full 6-visit cycle to all three parks (SOP AM06).
- **Data analysis and product development**—Data are summarized, analyzed, and prepared for reports and presentation following the procedures outlined in the ‘Data Analysis’ section below (see also SOP AM07—*Data Analysis and Reporting* [Carlson et al. 2018e]).
- **Product posting and distribution**—Finalized products are distributed to parks and other stakeholders, and/or posted to NPS clearinghouses. Report and presentation products are distributed to stakeholders as they are completed, and these products, in addition to the databases and scanned data sheets, are posted to the [NPS Integrated Resource Management Applications \(IRMA\) Data Store](#) on an annual basis (SOP AM07).

Table 3. Data processing steps and products for the GULN Amphibian Monitoring protocol.

Data type	Data stage (going in)	Processing step	Product name (going out)	Expected frequency of completion
Data sheets	N/A	1. Data sheets are filled-in by hand in the field.	Raw data sheets	Before leaving each site
	Raw	2. Data sheets are reviewed for completeness at the end of fieldwork.	Reviewed/verified data sheets	Before leaving each site
	Provisional	3. Data sheets are reviewed by the ecologist or crew leader for spelling, current taxonomy, and realistic values. When necessary, the photos are reviewed to ensure the species identifications were made correctly. Corrections are handwritten directly on the data sheet. If the Quality Control (QC) check results in any changes to species names, these changes are also recorded on the data sheet prior to its validation.	Validated data sheets	At the end of each field sampling day or within a week
	Accepted	4. Data sheets are signed as accepted and then digitally scanned.	Scanned, validated, and accepted data sheets	At the end of each field sampling day or within a week
	Accepted	5. Paper data sheets are managed as long-term records.	Local storage of accepted data sheets	Within three months of park visit
	Accepted	6. Scanned data sheets are published to NPS IRMA Data Store.	Offsite archive and publication of accepted data sheets	Within one year of a full 6-visit cycle to all three parks

Table 3 (continued). Data processing steps and products for the GULN Amphibian Monitoring protocol.

Data type	Data stage (going in)	Processing step	Product name (going out)	Expected frequency of completion
Photos/ image data	N/A	1. Digital photos are taken (1) at photopoints for each cluster (2) of the exposed ground beneath coverboards and (3) of any amphibians for which identifications are uncertain (4) of all amphibians found in the randomly-selected cluster for QC checks.	Raw photos	As soon as a coverboard is lifted or as needed for ID purposes
	Raw	2. All photos are downloaded. The QC photos are copied into a folder that is sent to the independent reviewer. This person must not see data sheets prior to viewing the photos and making their ID determinations.	Organized digital photos	At the end of each field sampling day or within a week

Table 3 (continued). Data processing steps and products for the GULN Amphibian Monitoring protocol.

Data type	Data stage (going in)	Processing step	Product name (going out)	Expected frequency of completion
Photos/ image data (continued)	Provisional	3. All photos are viewed on screen. Any out-of-focus images are discarded if duplicates are available. Otherwise, they are left for placeholder purposes. For any coverboards where an animal escaped, the photo is scrutinized on screen to identify the species, if possible. Each questionable ID photo and all QC photos are viewed on-screen by an expert in amphibian identification for that park, and the correct Latin name is recorded. Matches and mismatches in the QC check on species ID are recorded in a separate QC tracker spreadsheet, which is managed by the crew leader or protocol lead.	Reviewed digital images	At the end of each field sampling day or within a week
	Accepted	4. Photos are archived locally. Photopoint photos are reviewed for each cluster in order. Major vegetation changes are recorded and classified, and these classes may be used as a covariate at the cluster level.	Local archive of photos and validated image data	Within five months of a full 6-visit cycle to all three parks

Table 3 (continued). Data processing steps and products for the GULN Amphibian Monitoring protocol.

Data type	Data stage (going in)	Processing step	Product name (going out)	Expected frequency of completion
Amphibian and Reptile Monitoring Database	NA	1. Accepted data sheets are entered into the database.	Raw, entered datasets	Within several weeks of the field sampling day
	Raw	2. Data verification during data entry: typist checks his/her own work for accurate transcription of each page.	Partially verified datasets	Within several weeks of the field sampling day
	Raw	3. Data verification post-data entry: another staff member performs a 100% check for accurate transcription.	Partially verified datasets	Within several weeks of the field sampling day
	Raw	4. Data verification post-data entry: ecologist/protocol lead performs a 10% check of all data sheets for a given field season for accurate transcription.	Verified data	Within one month of a full 6-visit cycle to all three parks
	Provisional	5. Ecologist creates summary statistics and plots data to identify and flag outliers	Partially validated data	Within three months of a full 6-visit cycle to all three parks
	Provisional	6. Ecologist reviews species lists and checks IDs for unexpected records.	Validated data	Within three months of a full 6-visit cycle to all three parks.
	Accepted	7. Validated data are accepted and metadata are created for the dataset. If the protocol QAP is in place, these data are certified data.	Accepted data and the associated metadata	Within three months of a full 6-visit cycle to all three parks.

Table 3 (continued). Data processing steps and products for the GULN Amphibian Monitoring protocol.

Data type	Data stage (going in)	Processing step	Product name (going out)	Expected frequency of completion
Amphibian and Reptile Monitoring Database (continued)	Accepted	8. Database backends or Excel worksheets of accepted data are published to NPS IRMA Data Store.	Offsite archive and publication	Within four months of a full 6-visit cycle to all three parks.
	Accepted	9. Data are analyzed, and reports are written based on the results.	'2-year Summary Reports' reports and 'Status and Trends' reports	Two-year Summaries: 3 months after the end of the second year. Status and Trends: 6 months after the end of the 6th year.

Data Processing and Data Quality Levels

The data processing steps, their associated products, and their frequency of completion are listed in Table 3. Table 3 also introduces the three stages of data processing: raw, provisional, and accepted. Raw data are in their original form, either as a field data sheet, photo, or a raw entry into the database. Provisional data have undergone verification steps but are not suitable for general use. Accepted data (certified data if the QAP for the protocol is in place) are products from the provisional data step that have been validated, documented with metadata, and are fit for analysis and publication. These accepted or certified data sets are then documented with metadata using the current version of ESRI ArcCatalog by the data manager. This metadata document will accompany all archived annual data products on the GULN server and will be distributed with data requests and uploads to national databases. See GULN SOP AM06 for details.

Data Archiving

Instructions for archiving and posting data are included in GULN SOP—AM06. To summarize, after digital products are processed and approved (for reports) or accepted/certified (for datasets), the data manager archives them and prepares for posting them to the [Integrated Resources Management Applications](#) (IRMA) website. IRMA is the NPS clearinghouse for natural resource data and metadata. The types of products that are posted on IRMA for this project include two-year summary reports (alternate-years), status and trends reports (every six years), digital scans of data sheets, and Microsoft Excel exports of annual datasets from the NPS GULN Amphibian and Reptile Monitoring Database. In their unfinished or provisional forms, these products are generally stored only on the GULN server.

The timing of posting new products to IRMA is annually, if not more often. Products on IRMA can be shared with the public or classified as restricted access only. Public access is given to final, approved reports or to datasets that are accepted or certified and from which protected data have been withheld. Restricted access on IRMA may be used for provisional products or protected information.

The GULN data manager has created a GULN [Amphibian Monitoring Project](#) that houses all products uploaded to IRMA. Refer to the IRMA website for upload and product linking instructions.

When any product is posted on IRMA, the data manager creates for it a separate reference record that is specific to the IRMA platform, following instructions on the IRMA website. The reference record contains citation information, relevant metadata and keywords. This is done for all products including reports, other publications, datasets, or set of field sheets. The digital version of the product is uploaded in association with that reference, making it available for discovery. Most products are organized by park, unless they apply to multiple parks. Finally, where appropriate, the data manager also extracts species observations and imports them into [NPSpecies](#), which is the NPS database and application for maintaining park-specific species lists and observation data. NPSpecies is a component of IRMA.

Protected Information Procedures

Currently, none of the species known to use GULN coverboards or PVC pipes are listed as threatened or endangered by the U.S. Fish and Wildlife Service, nor are any of these species considered by the park to be rare or commercially valuable. Even so, the network and park staff wish to keep the public from easily locating PVC pipes and coverboards due to the potential that protected species may come to use them. An additional concern is that any non-prescribed manipulation of artificial cover objects may interfere with the sampling protocol and data quality. Instructions for managing protected data are included in the data management SOP, GULN SOP AM06.

Procedure for Revising the Protocol

Over time, revisions to both the protocol narrative and SOPs are expected. Careful documentation of changes to the protocol and a library of previous protocol versions are essential for maintaining consistency in data collection and for appropriate treatment of the data during data summary and analysis.

The steps for changing the protocol (either the protocol narrative or the SOPs) are outlined in SOP AM08—*Protocol Revisions* (Carlson and Segura 2018). The protocol narrative and each SOP contain a revision log to fill out each time the narrative or an SOP is revised. In this log, the GULN staff person briefly documents when and why the change was made and assigns a new version number. Revised protocol narratives must also undergo the editing process and be assigned a new report number by the National I&M Program Publication Manager. The new version of the SOP or protocol narrative is then archived in the appropriate GULN vital signs protocol folder on the GULN network drive.

Data Analysis and Reporting

Two-Year Summary Reports

The Gulf Coast Network provides a short-term summary report to each park once every other year. A complete description is provided in SOP AM07—*Data Analysis and Reporting*. To summarize, report writing begins after two years of data in the database (12 sampling visits) have passed the database validation step, and are considered an accepted database. For reporting purposes, the year begins in March, when detection rates have dropped and stabilized from their wintertime peak, particularly for PVC pipes (see Cheng 2017). The first section of the report is a brief and general overview of the project's objectives, duration and methods used in the park. Next, the report includes a summary of the GULN's efforts in the park during the period of interest. The bulk of the report is the project's results for amphibian detection, in the sections listed below. The report also describes weather and other covariate data collected over this time period and notes unusual conditions or events in the park.

The Gulf Coast Network provides the following information on the status of monitoring amphibians at two-year intervals.

1. A list of all species detected over the last two years, as well as a 'last recorded' date for those species on the park checklist that have not been detected in the past two years.
2. A table showing the total number of amphibians detected per site and per pipe or board across all visits during the reporting period (see example Table 4) with the most common species reported individually in addition to being included in the total per cover object type.
3. Figures depicting detection rates for each cover object type over time (see example Figure 9) where detection rates are calculated as the mean number of conspecific individuals per pipe or board, as in Figure 9, or as the proportion of all sampled boards or pipes containing at least one individual of that species.

Table 4. Example of a two-year data summary product, showing the numbers of amphibians detected on each visit for all coverboards and PVC pipes in a GULN park. This example table is based on pilot data that were collected at monthly intervals in one site at Gulf Islands NS, using 48 pipes and 30 coverboards. For the long-term project, there are 128 pipes and 64 boards checked every other month across two different sites at each of Gulf Islands NS and Jean Lafitte NHP&P, and 60 boards across three sites at San Antonio Missions NHP. The format of the tables will be adjusted accordingly.

Date	PVC:green treefrog	PVC: pine woods treefrog	PVC: squirrel treefrog	PVC:all species	Board: green- house frog	Board:all species
March 2015	0	6	0	6	5	8
April 2015	0	10	1	11	4	10
May 2015	0	3	1	4	1	1
June 2015	0	2	0	2	3	4
July 2015	0	2	0	2	1	1
Aug 2015	0	0	0	0	4	9
Sept 2015	0	5	0	5	8	9
Oct 2015	0	5	0	5	10	13
Nov 2015	1	12	2	15	35	36
Dec 2015	0	11	3	14	15	18
Jan 2016	1	2	2	5	14	15
Feb 2016	1	10	3	14	6	7
March 2016	1	6	0	7	13	15
April 2016	1	4	0	5	10	15
May 2016	1	6	1	8	3	4
June 2016	1	4	0	5	6	7
July 2016	0	2	0	2	2	3
Aug 2016	0	0	0	0	9	9
Sept 2016	0	4	0	4	9	12
Oct 2016	0	0	0	0	6	6
Nov 2016	0	7	0	0	1	2
Dec 2016	0	5	0	0	14	15
Jan 2017	0	7	0	0	6	11
Feb 2017	10	0	0	0	9	11

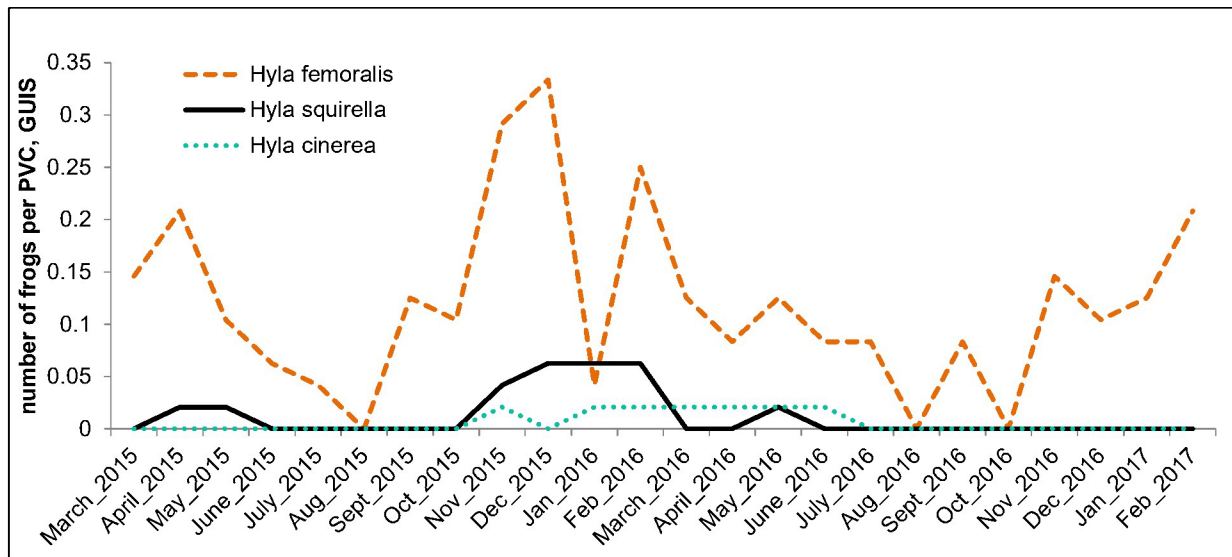


Figure 9. Example of a two-year data summary product, showing the mean number of treefrogs per PVC pipe in a GULN park. This example table is based on pilot data that were collected at monthly intervals in one site at Gulf Islands NS, using 48 pipes. As described for Table 4, the results presentation for the final, long-term project will be adjusted to suit the modified design.

Six-year Status and Trends Reports

At six-year intervals, the Gulf Coast Network provides a more in-depth report on the status of the amphibian assemblages using PVC pipes or coverboards and the trends in relative abundance for a few key species. Detailed descriptions of sections and analyses are included in SOP AM07. Like the two-year summaries, six-year report writing begins after the database containing all necessary data has passed validation steps to become an accepted database. These reports follow a format similar to the shorter summaries, except in the six-year reports, there is a section for statistical analyses and several sections for reporting results. Additionally, there is a conclusions section that discusses these findings in the context of previous six-year reports and in relation to park management concerns and potential environmental stressors that may be driving observed patterns.

Results sections for the report: The six-year report includes the following results components.

1. cumulative summaries of the three previous 2-year reports (combining figures and tables) plus a description of changes relative to the previous six-year reports;
2. graphical depiction of species richness over time in each park and each site, for invasive and native species separately;
3. graphical depiction of change in detection over time of any species of interest (frequency or relative abundance), even if they are not among the most common;
4. graphical depiction of changes in relative abundance over time of the focal, common species for that park; and
5. statistical analyses of trends over years for the focal common species for that park.

Statistical analyses for the report: As explained in SOP AM07, the Gulf Coast Network uses generalized linear mixed models to perform cross-year trend analyses on amphibian relative abundance for the most common, focal species. Each focal species within a park is analyzed separately. Generalized models are used to allow for non-Gaussian distributions, such as negative binomial or Poisson (for count data) or binomial (for proportions). Statistical analyses are performed in R, using statistical package lme4 (R Core Team 2014; Bates et al. 2015).

For each model, the response variable is the number of individuals per pipe or board, or for the less-often-detected species, the proportion of pipes or boards checked that contain at least one individual of that species. The main fixed effect is year, to test for a net increase or decrease over time (six or more consecutive years). One additional fixed effect is the study site (two per park in Jean Lafitte NHP&P and Gulf Islands NS, and three at San Antonio Missions NHP). Additional random effects and environmental covariates are included in the model, as detailed in SOP AM07. Following the approach taken by Cheng (2017) all covariates are included in a global model for each species, and then environmental covariates are dropped one at a time to produce a set of candidate models. The best-supported model among these is that with the lowest Akaike information criteria (AIC; Burnham and Anderson 2002). All models within six AIC units of the best-supported model, excluding more complex models with lower AIC, are compared to determine the range for each coefficient estimate or random effect variance estimate. See Cheng (2017) and SOP AM07 for additional details.

The primary trend analyses for each park are based on data going back to 2018, when the final design was implemented in each park. For the first report interval, only six years of data are available, but beyond that, analyses are more robust with 12-plus years. Whenever possible, pilot data are included in a supplemental analysis for that site on its own. Not all of the covariate data are available from the pilot study, but the primary consequence should be reduced power for detecting trends, rather than causing false trends to be observed.

Relative abundance considerations: By using relative abundance (counts per monitored object) to test for trends over time, the network assumes that this variable is, in some way, related to that species' true abundance at that site. Because the fraction of a population that uses artificial cover objects is unknown and may vary throughout the year, this metric does not represent the actual number of individuals in the local population. It can, however, be used as an index of whether that species is becoming more or less common over time, especially when also accounting for time-of-year effects and other variables that may potentially influence animal use of boards and pipes. The Gulf Coast Network makes every effort to keep the distinction between true and relative abundance clear while also recording variables that influence detection and occupancy of boards and pipes. Additional discussion of amphibian detection probability and its challenges are in the following sections.

Statistical power considerations: As was highlighted in the power analyses section, trend analysis of GULN amphibian monitoring data may have low power-of-detection. For example, the initial GULN design provided very low power (less than 45%) to detect a relatively substantial cumulative loss (54%) over a 10-year period. Although the GULN analyses are complicated by low statistical power, the network considers this an expected challenge for this type of study. Amphibians are

known to vary greatly in abundance both seasonally and across years (Thompson 2004; Cheng 2017). The seasonal or situational use of artificial cover objects will augment this variability, such that detecting true increases or declines in relative abundance may be difficult even for relatively common species.

The Gulf Coast Network has implemented several changes to the pilot study's monitoring design, with the goal of increasing statistical power to the generally-accepted threshold of 80% power, and an alpha level of 0.10, for detecting a 50% change in frequency or relative abundance over a 12 year period. One such change is to include a larger suite of covariates into the trend-analysis models. To the extent possible, the network also incorporates data on water-related changes, vegetation changes, anthropogenic influence, and other potential drivers. Finally, the network collects at least six years of data before performing trend analyses, because the power to detect trends increases over longer time periods. Data collected under this new design will be subjected to a new suite of power analyses coincident with the first status and trends report.

Detection probability considerations: The data collected by the Gulf Coast Network are best suited for monitoring trends over time at the park level and within species. These data are less appropriate for cross-species comparisons, because certain taxonomic groups use artificial cover objects more often than others (Zacharow et al. 2003; Glorioso and Waddle 2014). Yet even when comparisons are limited to a given species, there is still potential for a disconnect between the number of animals using the artificial cover objects and their actual population density at the site. For example, a disconnect could be caused by conspecific individuals changing their preferences for artificial cover objects over time, as may occur when there are increases or decreases in the number of natural cover objects at a site. To address this challenge, the network does not quantitatively record natural cover objects at the site, but it does photograph each cluster of four boards and six pipes at a set photopoint during each visit. These photographs are used to document major vegetation changes at and around each cluster. A second cause of a disconnect could be a temporal change in the probability that crew members detect and identify all amphibians using the board or pipe. The network assumes there is a low ($\leq 5\%$) probability of amphibian individuals escaping before detection and identification, and this probability is assumed to remain constant within species, both over time and among skilled observers.

Even with the supplemental data it collects, the network recognizes it cannot extrapolate its estimate of a species' relative abundance to the population at large. During reporting, trends are explained from a statistical perspective, and separately, interpretations are discussed with caution and in light of other changes observed on the landscape. Future projects may aim to quantitatively measure detection probabilities in GULN artificial cover objects and account these detection probabilities in the analyses. These steps are, however, outside the scope of the current protocol.

Personnel Requirements and Training

Roles and Responsibilities

The GULN project team consists of the network program manager, protocol lead, data manager, GIS specialist, and GULN bio-technician, plus available GULN interns and volunteers. The primary duties fall to the protocol lead, bio-technician and data manager, with general oversight from the program manager.

Network Program Manager

The network program manager is responsible for overseeing the implementation of this and other vital sign protocols. They ensure the Amphibian Monitoring Project is aligned with, and contributes to, overall network goals. The network program manager also provides support in budget, personnel, and logistical matters.

Protocol Lead

The protocol lead is the GULN network ecologist (GS-12) or other qualified GULN staff member designated by the GULN program manager. The protocol lead oversees all implementation of GULN amphibian monitoring and liaises as necessary with subject-matter experts and project advisors, park resource managers, and contractors or cooperators. The protocol lead organizes and facilitates amphibian monitoring at GULN parks. Specific tasks of the protocol lead include:

- leading protocol development and revision;
- developing the field sampling schedule across all projects;
- acquiring and maintaining appropriate permits (including research and state permits);
- communicating with subject-matter experts, advisors and park resource managers on project development;
- ensuring that all crew members are appropriately trained (procedures, taxonomy, safety);
- writing, updating and renewing sampling permits to parks
- tracking project sampling performance to ensure data quality;
- leading data analysis;
- leading report development and submission; and
- presenting project reports and findings as needed.

Data Manager

The primary duties of the data manager (GS-11) are to develop, manage, and update the database, direct all data through the data workflow (data entry to QA/QC to distribution), and serve as the key contact for all outside access to those data. The data manager also assists the protocol lead in obtaining necessary data sets for analysis. The data manager may also take part in amphibian sampling in parks.

Bio-technician

The GULN bio-technician (GS-7) is typically the field crew leader. In this role, they are responsible for organizing and completing field work consistent with all protocol SOP prescriptions, training new participants in protocol implementation, managing the Quality Control (QC) check on species ID for each visit, and ensuring correct taxonomic IDs of species in the field or from photographs. For an individual sampling event, the crew leader prepares sampling equipment, prints data sheets, coordinates sampling dates with involved park resource staff, assigns crew members their daily tasks, and leads safe and consistent field performance. After returning from the field, this person is responsible for cleaning and stowing equipment, reviewing and signing data sheets as accepted, and handing data sheets over to the data manager for data entry. The crew leader delivers the QC photos to the appropriate GULN staff person or outside expert for independent identification. They also discuss any questionable IDs and other data verification issues with the protocol lead prior to final data entry. If necessary, an outside taxonomic expert is contacted to ensure correct IDs.

The protocol lead, data manager and bio-technician are full-time GULN staff. All in-office duties including data entry, equipment maintenance, and support preparation are shared among GULN staff and available interns. Sampling and in-office work may include participation by volunteers.

Crew Qualifications

The protocol lead is expected to have an advanced degree in ecology. They must have demonstrated skills in quantitative design and statistical analysis as well as familiarity with the range of field conditions, sampling methods, and amphibian taxa in the three focal parks. The protocol lead should also have a minimum of one year of experience leading project teams or field crews.

The GS-7 bio-technician should have at least a four-year degree in biology, ecology, or environmental science with courses and skills in field ecology and herpetology. An advanced degree in the biological sciences with emphasis on a field discipline is preferred. The candidate must possess at least three months of experience in field crew leadership with demonstrated back-country and field safety skills. If sampling is handled through cooperative agreements, the non-GULN crew leader must be trained and supervised by the standard GULN crew leader. This collaborator must have similar or higher qualifications as the GS-7 bio-technician.

The GULN data manager qualifications are those defined for the position by applicable specialist knowledge, skills, and abilities (KSAs) at the GS-11 level. Protocol-related tasks are within those specialties and are trained for as needed within the GULN team.

Training

All GULN staff members are required to take annual first aid/cardiopulmonary resuscitation (CPR) training or refresher courses as needed to maintain current status. Amphibian identification skills are mentored within the GULN team through ongoing review and participation in field sampling and data verification and validation. Other GULN training includes participation in workshops, team safety and driving training, frequent review and update of amphibian handling practices, and specific training on related equipment and procedures (i.e., development of digital photography skill and practices and mentoring on proper sampling techniques). The appropriate GULN staff members, with

specific skills, provide in-house training. Outside training courses are arranged through the GULN program manager.

Safety

Safe operations are a network priority. The Gulf Coast Network developed several specific aspects of its amphibian monitoring program to ensure personnel safety. Crew safety is discussed in SOP AM01—*Safety*. Steps to ensure personnel safety include:

- All crew members are fully trained on the specific hazards of field sampling. The environmental hazards include off-trail travel and work, extreme heat and humidity, lifting, carrying and handling of heavy and hazardous objects, exposure to harmful plants and stinging insects, risk of drowning, falling, and encounter with hidden hazards under water or mud. When checking coverboards and PVC pipes, there is a risk of being bitten or stung by the animals that are using the cover object, such as wasps, snakes (venomous or non-venomous), other reptiles or certain amphibians (e.g., amphiumas and sirens). The standard procedure is to maintain safe distance when possible and avoid any contact with reptiles, especially venomous snakes. Crew members are instructed to avoid handling amphibians as well, except for any essential ID verification photographs. Amphibians are generally safe to handle, although their skin secretions can be irritating to the eyes (e.g., narrow-mouthed toads or members of Bufonidae). If an amphibian is handled, crew members must avoid touching their face until their hands are clean. Training in proper field techniques is ongoing throughout the sampling year, and each sampling visit begins with a crew safety and procedural briefing on the Job Hazard Analyses (JHA) that are associated with this protocol.
- The Gulf Coast Network has developed two JHAs for its amphibian monitoring field work (see the Appendices in SOP AM01 *Safety—Version 1.0* (Carlson et al. 2018c)). One is for driving safety and the other is for field work safety. These JHAs are modeled after examples available from the NPS I&M Division, other networks, and from parks. The JHAs are reviewed by all crew members and signed off on once per year, with signed copies maintain in network files.
- The Gulf Coast Network has developed a standardized trip-plan for all network monitoring and sampling events. This trip plan identifies the mission, its timeline, salient events, and major routes. A GULN point of contact (POC) is identified, together with a trip check-in schedule. In addition, each project-specific trip plan identifies key contact persons at the project park. A trip plan is created and filed by the crew leader before each sampling visit, and trip plans are archived as network project records. Upon arrival to the park, the crew leader contacts the network and park POCs. The same procedure is completed at the end of the day. If the network POC does not hear from the field crew by 7 p.m., they contact them directly. If the field crew cannot be reached, park emergency personnel are contacted.
- In conjunction with above crew safety measures and training, all GULN crew members are issued a network cellular telephone with text capabilities. These phones enable the crew to reach GULN offices or other assistance as needed. All sampling sites in all three parks are known to have reliable cellular service.

- Network vehicles contain a first-aid kit and bottled water. Crew members are also instructed to bring and use the appropriate field clothing, water, sunscreen, insect repellent, hand sanitizer and snake sticks, as are listed in the field equipment list (SOP AM02—*Preparation for Sampling and Equipment List*). All crew members are required to carry snake sticks in the field, and they must have clean hands and boots upon arriving to a site.

Preventing Harm to Amphibians

The amphibians being monitored through this protocol are valuable park resources that are protected under the NPS Mission and regulations. This taxonomic group is recognized as being vulnerable to potential harm from many human activities and actions, including those associated with sampling and monitoring. To ensure amphibian well-being, the network has developed specific practices and measures to protect amphibians from harm in the field and reduce risks of pathogen and parasite transfer between parks. Practices include:

- No animals are collected or removed from the parks. Crew members may handle the animal while photographing it for ID verification or as evidence of a new record for the park. This handling is done with care and respect for the animal's well-being. Otherwise, amphibians (or other animals) found during sampling are not handled. The one exception to this policy is if the host park resource manager or other park official requests a specimen; in which case, project staff can provide one, and the park assumes responsibility for its custody and use.
- No animals are intentionally harmed or sacrificed in handling or while pipes or boards are being checked. All sampling methods and practices are developed to reduce or eliminate accidental death to the degree possible.
- Crews are trained in safe handling practices for amphibians. Moist-skinned salamanders and frogs are handled with wet hands. Specific guidance on animal handling is provided in SOP AM03—*Field methods for amphibian monitoring*. The protocols for handling and cleanliness measures follow recommendations by the American Society of Ichthyologists and Herpetologists (Beaupre et al. 2004), the Canadian Council on Animal Care (CCAC 2004), and Heyer et al. 1994.
- None of a park's artificial cover objects are used in a different park. Waders, clothing, and equipment are cleaned with soap and water and bleach-rinsed between parks and non-contiguous park units to avoid transfer of pathogens and micro-organisms. Crews are provided alcohol-based hand-sanitizer to use as needed to clean up between specimens.

Operational Requirements

Annual Workload and Field Schedule

Gulf Coast Network amphibian monitoring can be divided into two parts: field work and office work. For field work, each park is visited for one day or two consecutive days, six times per year, by a crew of two people. This crew can consist of two GULN staff members, one GULN staff person and an outside participant, or no GULN staff members when work is completed through a cooperative agreement. At least two weeks prior to the trip, the field crew leader contacts the park to confirm dates and availability of field support, if needed. The crew leader also prepares equipment and prints data sheets just before departure. Data collection for a given visit takes place on a one to two day visit to the park, although significant travel may be required to reach San Antonio Missions NHP and Gulf Islands NS, possibly including one or two overnights. Sampling is delayed during severe weather, while the crew takes shelter at the park's visitor center. The time and expenses associated with field work are detailed separately for each park in the Budget Considerations section below.

After the park visit is complete, one person cleans and stows equipment (crew leader, as described previously). This person also downloads and organizes photos, researches uncertain IDs using the photos and taxonomic guides, manages the QC check on species ID, downloads data from continuous environmental data recorders, reviews all data sheets, and gives approved data sheets to the data manager. The data manager subsequently oversees data entry and data QA/QC measures. After the database is validated and accepted for subsequent use and distribution, the protocol lead uses these data for analysis and report writing. To see the costs and person-effort associated with these different phases of office work, see the Budget Considerations section below. The timeline for accomplishing each of these tasks is provided in the Data Management section.

Facility and Equipment Needs

The GULN network office is the center of operations for field work preparation, data entry, data management, data analysis, and project document development. This work is done with available network office facilities and computers. Field sampling occurs in two sites at Jean Lafitte NHP&P, two sites at Gulf Islands NS and three sites at San Antonio Missions NHP. Typically, equipment is not needed from the parks, although their visitor center facilities serve as the human support element for field crew, including water fountains and restrooms. The network provides the necessary equipment, including field camera, hand-held infrared thermometer for surface temperature and hand-held weather stations. They also provide continuous data loggers that are left in each transect and are repeatedly downloaded in the field. These units will occasionally be switched out for servicing and battery recharge. The network provides additional field supplies including snake sticks, rubber boots/waders, first-aid kit, and hand sanitizer if the network is completing the work. Otherwise, it is the responsibility of cooperators to provide these items to their field crew. GPS units are not typically needed but may be provided to help a relatively new crew leader locate the clusters. Travel by GULN staff to and from each park is by government vehicle. A list of field equipment is provided in SOP AM02—*Preparation for Sampling and Equipment List* (Carlson et al. 2018b).

Budget Considerations

The annual budget for the GULN amphibian monitoring effort is \$20,818, along with a one-time cost of \$6,486. This budget is calculated by first estimating the one-time costs, field costs, and management costs that may apply to any sampling site. Using these calculations, the annual costs specific to each park are estimated separately, so they can be summed for the final value. The breakdown of these budget components is provided below. Hourly wages for each GS-level are based on the 2017 salary tables.

Background for Estimates

Implementation of any site-based sampling project involves several discrete components that contribute to the cost. For this project, the three major components are (1) set-up or one-time costs; (2) annual field data collection costs, and (3) annual project costs for data management, project management and writing.

Set-up and One-time Costs:

There are two one-time costs in this budget: start-up equipment purchases and first-time report writing. For set-up costs, equipment purchases are estimated at \$1,000 per park $\times$ 3 parks = \$3,000. For first time report-writing and analyses, it is assumed that the first time takes longer than subsequent times. The Gulf Coast Network adds three extra days for the first two-year report and six additional days for the first six-year report. For a GS-12 ecologist, the hourly wage is \$34.58, but this is increased to \$48.41 when 40% benefits are added. Thus, the one-time cost is \$387.28 per 8-hour day $\times$ 9 days = \$3,485.52. The rounded-up sum of the one-time costs is \$6,486.

Annual Field Data Collection Costs:

- Cost of field crew salary while conducting field work. For these calculations, sampling at each park is assumed to be completed in one day, six times per year. Sampling is conducted by a team of two and may consist of two GULN staff, one GULN staff with assistance from park staff, or a team of two using a cooperative agreement with a local university.
 - If the team of two is from the network, the costs are estimated based on a lowest-step GS-11 biologist and GS-07 biologist/tech scale from GSA, using a 40% fringe benefits cost. A GS-07 has a \$19.49 hourly rate, which amounts to \$27.28 when benefits are included. For six 12-hour days per year, the GS-07 costs \$1,964.16. A GS-11 has a \$28.85 hourly rate, which amounts to \$40.39 including benefits. Thus, the GS-11 costs \$2,908.08 for six 12-hour days per year, and the combined cost of crew is \$4,872.
 - An alternative arrangement is that the GS-07 takes a three day trip to a more-distant park where a NPS staff person is available to complete the crew. For six three-day trips per year, each consisting of 8-hour days, the GS-07 costs \$3,928.
- Cost of field crew travel to and from sites (includes vehicle and overnight travel costs where needed). These are calculated separately for each park, and for Gulf Islands NS, they are combined with the cooperator's field crew salary as a lump sum of \$6,000. Current travel

cost estimates for the other parks are \$300 per year for Jean Lafitte NHP&P and \$1,200 per year for San Antonio Missions NHP.

- Cost of sampling equipment replacement and supplies (includes long-term equipment such as coverboards and PVC pipes, and consumable supplies). These are not listed specifically in this budget, but should cost less than \$100 per year for recurring expenses.

Annual Project Cost for Data Management, Project Management & Writing

- Cost of post-sampling data handling and management. This cost can be expressed as a fixed allocation of office time (30%), based on the number of person-days spent in the field. This calculation assumes a network-staffed crew of a GS-11 and GS-07 and a field effort consisting of six 12-hour days per year. To calculate data management costs, the standard is that each day in the field requires 30% of an 8-hour office day (2.4 hours) for each crew member to complete post-sampling activities. For the amphibian project, the annual cost for each park is calculated as six trips per year $\times$ 2.4 hours = 14.4 hours. The hourly wages for the GS-07 and GS-11 positions are explained in the Field Data Collection section above. For the GS-11 position, the cost is 14.4 hours $\times$ \$40.39 = \$581.62 per park. For the GS-07 position, the cost is 14.4 $\times$ \$27.28 = \$392.83 per park. Totaled across both crew members, the annual cost per park is \$974, rounded to the nearest dollar. For the three parks combined, the cost is \$2,922.
- Cost of time spent by the protocol lead with park communications, scheduling, permit writing and report writing. This cost can be expressed as a fixed allocation of office time (10%), based on the number of person-days spent in the field (see explanation above), for the GS-12 Ecologist. Ten percent of an 8-hour office day is 0.8 hours. Each park is visited six days per year, such that 4.8 hours of GS-12 effort is required per park. The hourly wage for the GS-12 position is explained in the Set-up and One-time Costs section above. The recurring annual cost is 4.8 hours $\times$ \$48.41 per hour = \$232 per park, rounded to the nearest dollar. For the three parks combined, this equals \$696.

The network samples each park using a different combination of network staff, park staff or through a cooperative agreement. To estimate the overall budget, the costs for each park are calculated separately, and then summed to create a total estimated budget. Under this format, costs associated with data and project management are divided evenly among the parks and added to each park's total annual cost.

Annual Totals for Park-specific Costs

- Gulf Islands NS—This park is currently monitored through a cooperative agreement with the University of West Florida. Cost for annual sampling is \$6,000. Adding \$1,206 for data and project management brings the total to \$7,206.
- Jean Lafitte NHP&P—This park is currently monitored by a team of two GULN staff members assuming a 12-hour day, six times per year for a total annual estimate of \$4,872 (see Field Data Collection Costs above). Adding \$300 for annual fuel costs brings the total to \$5,172. Finally, adding \$1,206 for data and project management brings the total to \$6,378.

- San Antonio Missions NHP—This park is currently monitored by one GULN staff member traveling to the site. Sampling is conducted with park staff assistance. The estimated salary for the GS-07 biologist is three 8-hour days of time, totaling to \$3,928 per year (see Field Data Collection Costs above). There are also travel costs of \$350 per trip (\$2,100 per year) for an annual total of \$6,028. Finally, adding \$1,206 for data and project management brings the total to \$7,234.

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Appendix A: Sampling Sites for Amphibian Monitoring and Arrangements of PVC Pipes and Coverboards

Summary

This appendix outlines site selection and locations of artificial cover objects used in *Monitoring Amphibians in Gulf Coast Network Parks: Protocol Narrative*. The Gulf Coast Network includes eight National Park units, but based on initial scoping and pilot data, the amphibian monitoring protocol currently applies to only three parks: Gulf Islands National Seashore (GUIS), Jean Lafitte National Historical Park and Preserve (JELA), and San Antonio Missions National Historical Park (SAAN). The rationale for selecting study sites within parks and distributing the coverboard and PVC pipes within sites are described in this document. All three parks follow the same arrangement of artificial cover objects within sites, with some adjustments to the SAAN layout because of its smaller size and lack of success with PVC pipes during the pilot study. Additional details and justifications are provided in the protocol narrative.

Figures A-1 through A-4 depict the approximate locations of coverboards and PVC pipes for both the pilot study period (2011–mid-2017) and for subsequent long-term monitoring (late 2017 or early 2018 onward). The Naval Live Oaks Area of Gulf Islands NS and the Barataria Preserve of Jean Lafitte NHP&P each have 64 coverboards and 128 pipes, which are split evenly between two sampling sites in similar habitat types (Figures A-1 and A-2). The main unit of San Antonio Missions NHP has 60 coverboards distributed evenly between three sites, but no PVC pipes. For San Antonio Missions, the pilot study layout is shown in a separate figure (Figure A-3) from the final layout (Figure A-4), but for the other two parks, the pilot and final layout are depicted in a single composite image.

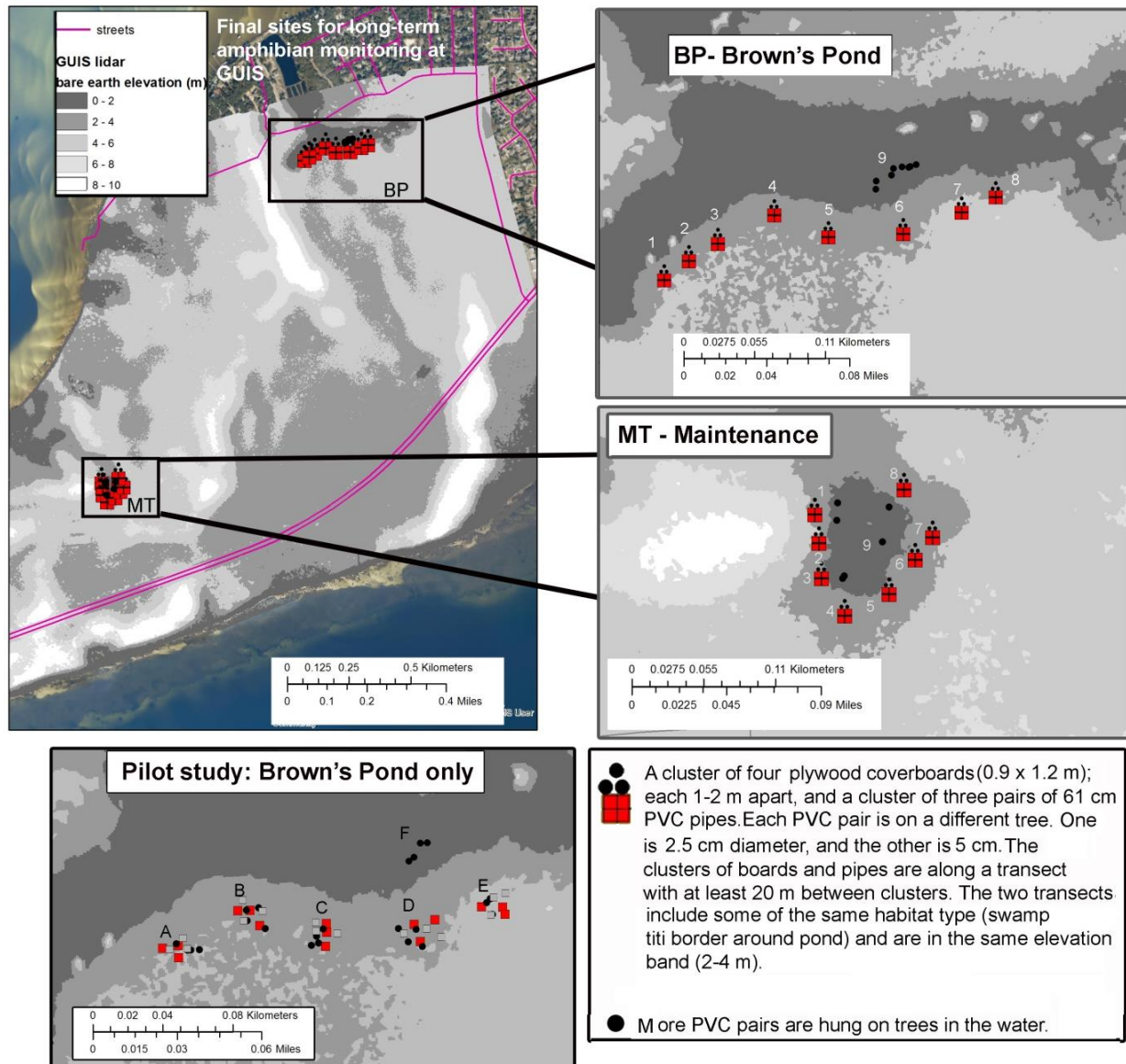


Figure A-1. Locations and site sampling layouts for amphibian monitoring in the Naval Live Oaks Area of Gulf Island National Seashore (GUIS), which is located near Gulf Breeze, Florida. The pilot study was conducted from 2011–2017, and the final sampling protocol at BP and MT was implemented in early 2018.

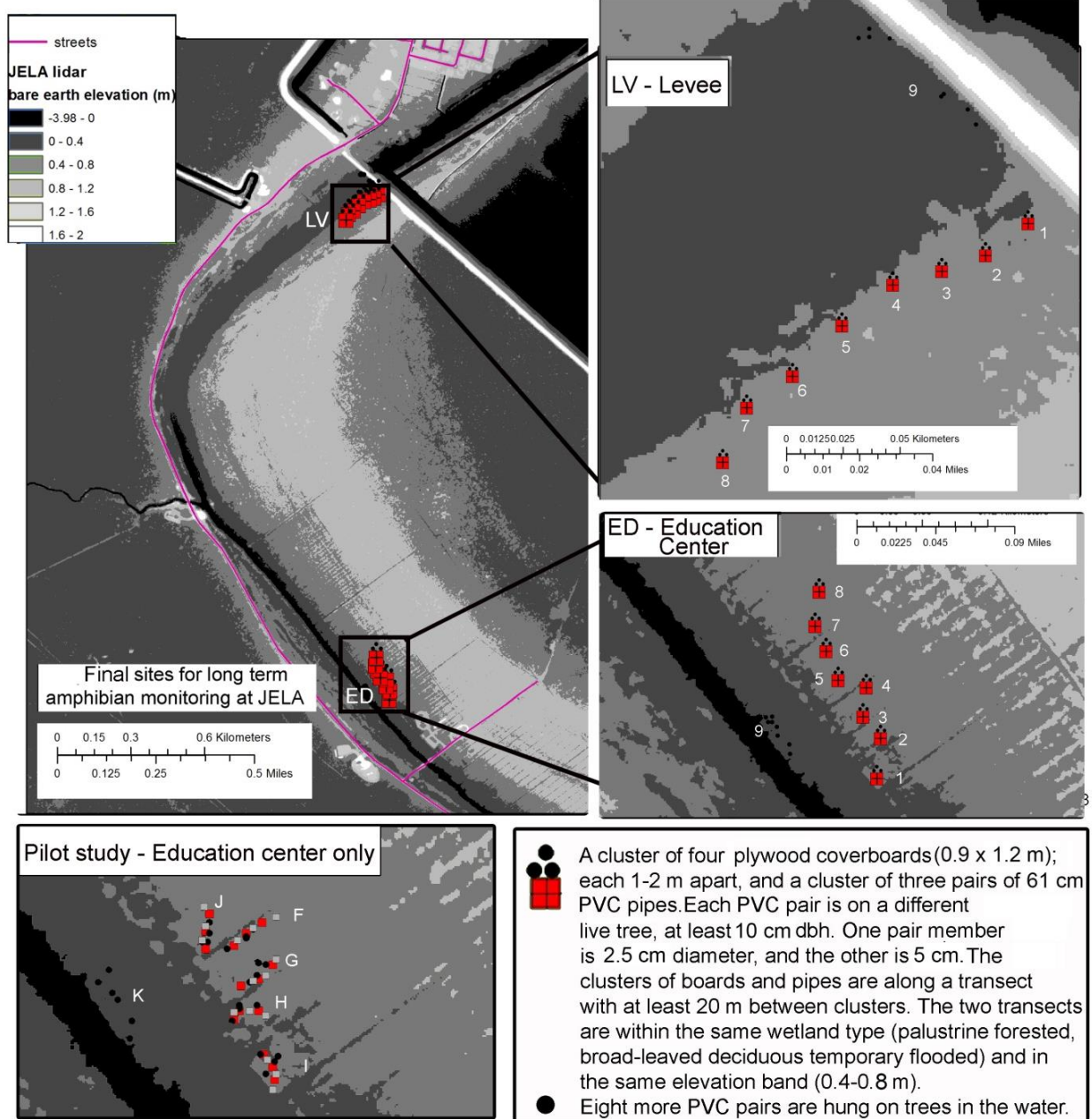


Figure A-2. Locations and site sampling layouts for amphibian monitoring in the Barataria Preserve of Jean Lafitte National Historical Park and Preserve (JELA), which is near Estelle, Louisiana. The pilot study was conducted from 2011–2017, and the final sampling protocol at LV and ED was implemented in late 2017.

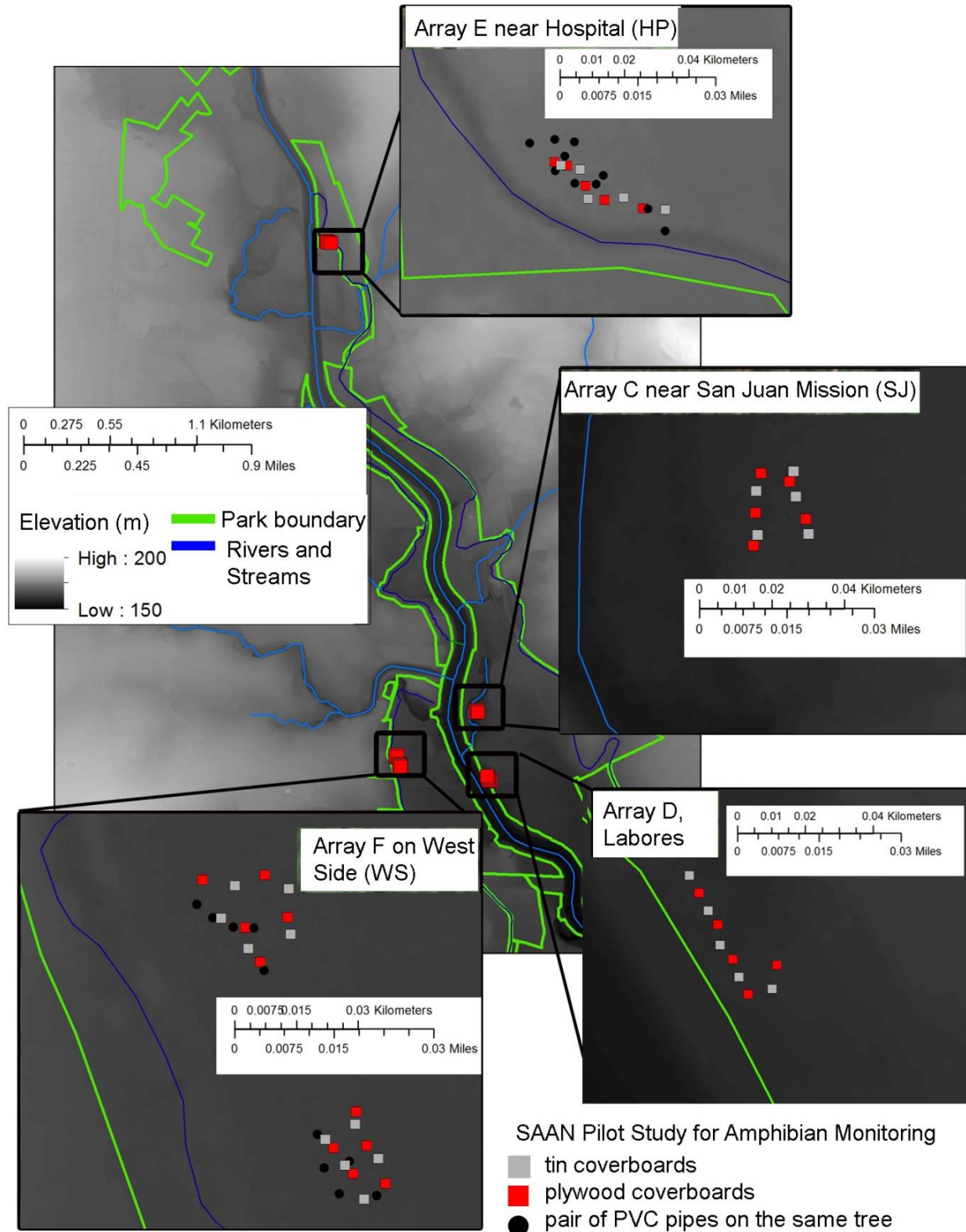


Figure A-3. Locations and site sampling layouts for the pilot phase of amphibian monitoring at San Antonio Missions National Historical Park (SAAN). The pilot study was from 2011–2017.

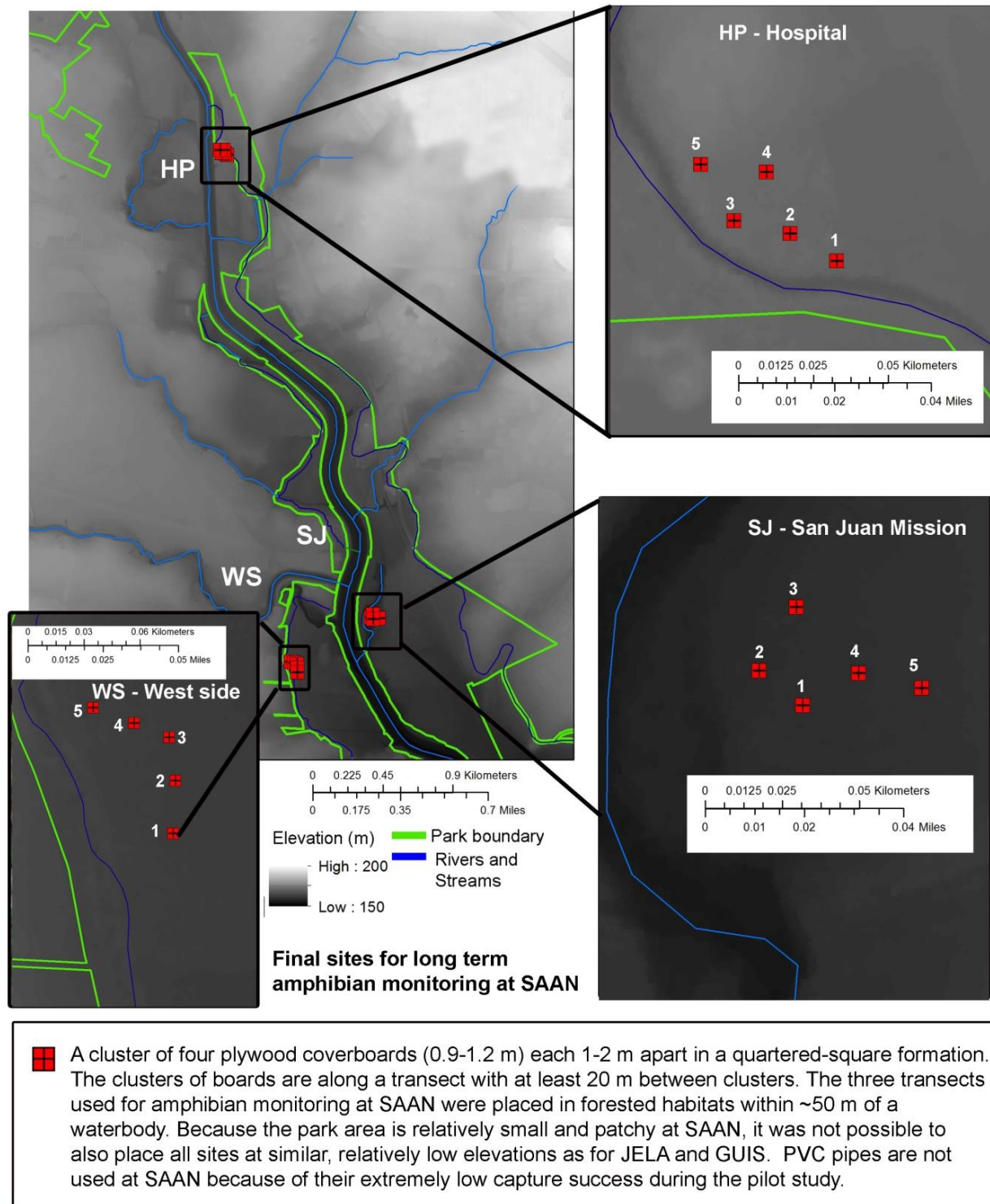


Figure A-4. Locations and site sampling layouts for amphibian monitoring at San Antonio Missions National Historical Park (SAAN). The final sampling protocol in three sites at SAAN (WS, SJ and HP) was implemented in early 2018.

Overview of Site Selection

The planning phase for amphibian monitoring was initiated by the Gulf Coast Network in 2007 and ended in 2011, with a finalized methodology and sampling frame for pilot data collection. During the five-year planning phase, GULN staff engaged Dr. J. Whitfield Gibbons and Dr. Kurt Buhlmann of the University of Georgia's Savannah River Ecology Laboratory as consultants and collaborators for the amphibian monitoring program development. The network also sought feedback from park management to identify areas for initial monitoring efforts. Early on, it was decided that sites would not be selected with the intention of making park-wide inference, but would instead focus on selected areas of particular management interest or importance to the park. Four references were fundamental in guiding the project's sampling design and monitoring approach: Dodd (2003), Anderson and Seigel (2003), Seigel and Doody (1996), and Graeter et al. (then in prep, but subsequently published in 2013).

The criteria for selecting sites for pilot data collection were as follows:

- sites were suitable for housing viable amphibian populations;
- they were relatively easy to access and traverse on foot;
- they were not immediately visible to the public; and
- they were of particular interest from a management perspective.

To accommodate the diverse sampling techniques the network planned to use, the sites also needed to have trees for hanging PVC pipes (cover objects for treefrogs), preferably targeting trees with a diameter at breast height (DBH) greater than 10 centimeters (3.9 inches [in]), have some relatively dry ground for coverboards (cover objects for salamanders and toads), and have an adjacent waterbody for minnow traps (for monitoring aquatic salamanders, *Lithobates* frogs and their tadpoles). Using these standards, network staff visited, assessed and conducted exploratory efforts in one or more sites within the parks. The pilot study sites were fully established by 2011, and these were sampled for six months to five-plus years. Sampling took place in each site once per month using one or more of the three following passive techniques: PVC pipes on trees, tin and plywood coverboards on the ground, and minnow traps in standing water. The locations, duration, and success of data collection in these sites are described in Carlson (2018).

Only three GULN parks had amphibian detection rates that were sufficiently high to continue monitoring through the end of the pilot phase in mid-2017. These parks were Gulf Islands NS (one site at Brown's Pond), Jean Lafitte NHP&P (one site at the Education Center), and San Antonio Missions NHP-Missions (four sites). The six pilot study sites are depicted in Figures A-1, A-2 and A-3. At the end of the pilot phase, the data were analyzed to determine if sample sizes provided sufficient power to detect trends and to assess the value of the different techniques. The results of these analyses are summarized in Carlson (2018).

With regards to the spatial sampling frame, timing, and passive techniques used, it was determined that:

- each park should have at least two replicate sites where monitoring takes place;
- all sites should follow similar sampling designs and have similar numbers of artificial cover objects across the three parks. Sample sizes were not standardized across parks in the pilot study, as described in the next section;
- tin coverboards are less effective at attracting amphibians than plywood coverboards, so only plywood coverboards should be used;
- minnow traps do not capture enough amphibians to warrant further use in any of the three parks;
- PVC pipes are not an effective monitoring tool at SAAN, although they are effective at JELA and GUIIS;
- sampling frequency should be reduced to alternate months rather than every single month, because the statistical power is expected to be similar, and the reduced frequency would save network time and resources.

Sample Sizes within Parks

During the pilot phase of data collection, sampling sizes were unequal across the three parks. The single site at Gulf Islands NS had 48 pipes and 30 coverboards (Figure A-1 pilot study inset), the single site at Jean Lafitte NHP&P had 52 pipes and 30 coverboards (Figure A-2 pilot study inset), and the four sites at San Antonio Missions NHP had a total of 40 pipes and 50 coverboards (Figure A-3). One of the sites at San Antonio Missions had 20 boards and 20 pipes (Array F), another had 10 boards and 10 pipes (Array E), and the remaining two each had 10 boards only (Array C and D). For the final proposed monitoring plan, sample sizes and arrangements are standardized across sites and parks. The one exception is that San Antonio Mission NHP's coverboards are divided among three rather than two sites, and the park lacks PVC pipes. This is because the sampleable areas are smaller at San Antonio Mission NHP, and PVC pipes are unsuccessful there. The long-term sampling designs for Gulf Islands NS and Jean Lafitte NHP&P include two sites per park that are in the same contiguous park unit and represent the same or similar habitat and elevation band (Figures A-1 and A-2). Each site has 32 coverboards and 64 pipes, totaling to 64 boards and 128 pipes per park. For San Antonio Missions NHP, each site will have 20 coverboards, totaling to 60 boards for the park. Changes from the pilot study include:

1. dropping one site from San Antonio Missions NHP (array D),
2. establishing one new site in the Naval Live Oaks Area of Gulf Islands NS,
3. establishing one new site in the Barataria Preserve of Jean Lafitte NHP&P, and
4. adding, moving, or removing boards and pipes from existing sites to match the layout described in the following section.

Layout of Artificial Cover Objects within Sites

Following examples described by Dodd (2003), the coverboards are placed in clusters of four in a quartered-square arrangement along a transect through the target habitat. Each plywood board is sized 0.9×1.2 meters and is placed 1–2 meters (3.2–6.5 feet [ft]) from the others in the same cluster, with some flexibility to accommodate trees and other obstacles. The clusters are placed at least 20 meters (65.6 ft) apart, and there are eight clusters per site at Gulf Islands NS and Jean Lafitte NHP&P and five clusters per site at San Antonio Missions NHP. Each cluster is numbered 1–8, and the boards within the cluster are, for example, 1.1, 1.2, 1.3, and 1.4 for cluster 1, and 2.1, 2.2, 2.3, and 2.4 for cluster 2. Cluster identification (ID) numbers are included in Figures A-1, A-2 and A-4. At Gulf Islands and Jean Lafitte, each cluster of four coverboards also has three pairs of PVC pipes hung in the closest three trees that are large enough to support PVC pipes, using only trees that are greater than 10 centimeters (3.9 in) DBH unless only smaller trees are available. The two PVC pipes hung from the same tree have the same ID number, but one pipe in a pair is 2.5 centimeters (1 in) in diameter, labeled ‘S’ for small, and the other pipe is 5 centimeters (2 in) in diameter, labeled ‘L’ for large. Both pipe types are 61 centimeters (2 ft) long. The pipe ID numbers are, for example, 1.1S, 1.1L, 1.2S, 1.2L, 1.3S, 1.3L for cluster 1, and 2.1S, 2.1L, 2.2S, 2.2L, 2.3S, 2.3L for cluster 2. A total of 48 pipes are associated with the eight clusters of coverboards. The remaining 16 pipes (eight pairs) are hung from trees that are growing in the nearby low areas that are either permanently or frequently flooded. These pipes are coded as 9.1S–9.8S for the smaller pipes, and 9.1L–9.8L for the larger pipes (Figures A-1 and A-2).

LiDAR data and GIS habitat maps were used to place transects within a single elevation band in one forest type for a given park. In Gulf Islands NS, both transects are near waterbodies and stay within a single elevation band of 2–4 meters (6.5–13.1 ft), following a curved transect (Figure A-1). In Jean Lafitte NHP&P, each transect is in bottomland hardwood forest, and it follows a straight line at 0.4–0.8 meters (1.3–2.6 ft) elevation. The transects also remain approximately 30 meters (98.4 ft) from and parallel to the Bayou de Famille (Figure A-2). At San Antonio Missions NHP, transects are straight lines through forested habitats, straight or curved as necessary to fit in available habitat fragments (Figure A-4). They are within 50 meters (164 ft) of a waterbody, but are not within a single elevation band because of limited available habitat for sampling.

Appendix B: Amphibian Species Checklists for Monitored Gulf Coast Network Parks

Table B-1. GUIS species checklist adapted from Mohrman and Qualls (2008), with one addition from GULN's pilot work at Naval Live Oaks. The first 20 species on the list were recorded in the Naval Live Oaks Area as well as, in some cases, other sections of GUIS. The final six species were only documented in GUIS sections other than Naval Live Oaks. The 10 species marked with a "+" in either of the first two columns were detected during the GULN pilot work in pipes or coverboards (2011–2017). Of these detected species, only *Hyla cinerea*, *H. femoralis*, *H. squirella* and *Eleutherodactylus planirostris* use these cover objects often enough for the GULN to monitor of their relative abundances (see Carlson 2018 for details). The 2004–2006 survey data and historic records are provided by Mohrman and Qualls (2008). The 1992–1994 survey is by Seigel and Doody (1996) and the 1997 survey is by Seigel et al. (1997). Taxonomic names in the table follow Crother (2017).

NPS survey when first recorded	Species name	Common name	GULN cover-board	GULN pipe	GULN casual or minnow trap
2004–2006	<i>Acris gryllus</i>	Southern cricket frog	+	–	+
2004–2006	<i>Amphiuma means</i>	Two-toed amphiuma	–	–	+
2004–2006	<i>Anaxyrus quercicus</i>	Oak toad	+	–	+
2004–2006	<i>Anaxyrus terrestris</i>	Southern toad	+	–	+
2004–2006	<i>Eleutherodactylus planirostris</i>	Greenhouse frog	+	–	+
1997	<i>Eurycea cirrigera</i>	Southern two-lined salamander	–	–	–
2004–2006	<i>Eurycea quadridigitata</i>	Southern dwarf salamander	+	–	–
2004–2006	<i>Gastrophryne carolinensis</i>	Eastern narrow-mouthed toad	+	–	–
2004–2006	<i>Hyla cinerea</i>	Green treefrog	–	+	+
2004–2006	<i>Hyla femoralis</i>	Pine woods treefrog	+	+	+
2004–2006	<i>Hyla gratiosa</i>	Barking treefrog	–	–	–
2004–2006	<i>Hyla squirella</i>	Squirrel treefrog	+	+	+
1997	<i>Notophthalmus viridescens</i>	Eastern newt	–	–	–

¹*Plethodon mississippi* was recorded in Naval Live Oaks and Davis Bayou by Seigel and Doody (1996) and in Davis Bayou by Mohrman and Qualls (2008). This species in Naval Live Oaks is now referred to as *Plethodon grobmani*, but in Davis Bayou, the name remains *P. mississippi* (Powell et al. 2016).

²*Lithobates catesbeianus* was recorded in 1996 and 2004–2006 in Davis Bayou, but was not recorded for Naval Live Oaks at that time.

Table B-1 (continued). GUIS species checklist adapted from Mohrman and Qualls (2008), with one addition from GULN's pilot work at Naval Live Oaks. The first 20 species on the list were recorded in the Naval Live Oaks Area as well as, in some cases, other sections of GUIS. The final six species were only documented in GUIS sections other than Naval Live Oaks. The 10 species marked with a "+" in either of the first two columns were detected during the GULN pilot work in pipes or coverboards (2011–2017). Of these detected species, only *Hyla cinerea*, *H. femoralis*, *H. squirella* and *Eleutherodactylus planirostris* use these cover objects often enough for the GULN to monitor of their relative abundances (see Carlson 2018 for details). The 2004–2006 survey data and historic records are provided by Mohrman and Qualls (2008). The 1992–1994 survey is by Seigel and Doody (1996) and the 1997 survey is by Seigel et al. (1997). Taxonomic names in the table follow Crother (2017).

NPS survey when first recorded	Species name	Common name	GULN cover-board	GULN pipe	GULN casual or minnow trap
1992–1994	<i>Plethodon grobmani</i> ¹	Southeastern slimy salamander	+	–	–
2004–2006	<i>Pseudacris crucifer</i>	Spring peeper	–	–	–
1992–1994	<i>Pseudacris ornata</i>	Ornate chorus frog	–	–	–
2004–2006	<i>Lithobates clamitans</i>	Bronze frog	–	–	+
GULN 2011–2017	<i>Lithobates catesbeianus</i> ²	American bullfrog	–	–	+
2004–2006	<i>Lithobates grylio</i>	Pig frog	–	–	+
2004–2006	<i>Lithobates sphenoccephalus</i>	Southern leopard frog	–	–	+
Historic 1950's	<i>Pseudotriton montanus</i>	Mud salamander	–	–	–
Historic 1950's	<i>Eurycea guttolineata</i>	Three-lined salamander	–	–	–
2004–2006	<i>Pseudacris nigrita</i>	Southern chorus frog	–	–	–
2004–2006	<i>Plethodon mississippi</i>	Mississippi slimy salamander	–	–	–
2004–2006	<i>Hyla versicolor</i>	Gray treefrog	–	–	–
1997	<i>Hyla andersonii</i>	Pine barrens treefrog	–	–	–

¹*Plethodon mississippi* was recorded in Naval Live Oaks and Davis Bayou by Seigel and Doody (1996) and in Davis Bayou by Mohrman and Qualls (2008). This species in Naval Live Oaks is now referred to as *Plethodon grobmani*, but in Davis Bayou, the name remains *P. mississippi* (Powell et al. 2016).

²*Lithobates catesbeianus* was recorded in 1996 and 2004–2006 in Davis Bayou, but was not recorded for Naval Live Oaks at that time.

Table B-2. JELA species checklist adapted from Anderson and Siegel (2003), with one addition from GULN's pilot work at the Barataria Preserve. The 11 species marked with a "+" in either of the first two columns were detected during the GULN pilot work in pipes or coverboards at that site (2011-2017). Of these detected species, only *Hyla cinerea*, *H. squirella*, *H. avivoca*, *Incilius nebulifer*, *Gastrophryne carolinensis* and *Eleutherodactylus planirostris* use artificial cover objects often enough for the GULN to monitor of their relative abundances. This conclusion is based on from the GULN pilot work at the Education Center site at JELA, which is described in detail in Carlson (2018). The 2001–2002 survey was by Anderson and Siegel (2003) and the 1988 survey was by Rossman and Demastes (1989). Taxonomic names in the table follow Crother (2017).

Survey when first detected	Species name	Common name	GULN board	GULN pipe	GULN casual or minnow trap
2001–2002	<i>Acris blanchardi</i> ¹	Blanchard's cricket frog	+	–	+
2001–2002	<i>Ambystoma texanum</i>	Small-mouthed salamander	–	–	–
2001–2002	<i>Amphiuma tridactylum</i>	Three-toed amphiuma	–	–	+
2001–2002	<i>Incilius nebulifer</i>	Gulf Coast toad	+	–	+
2001–2002	<i>Eleutherodactylus planirostris</i>	Greenhouse frog	+	–	+
2001–2002	<i>Eurycea paludicola</i> ²	Western dwarf salamander	+	–	–
2001–2002	<i>Gastrophryne carolinensis</i>	Eastern narrow-mouthed toad	+	–	+
2001–2002	<i>Hyla avivoca</i>	Bird-voiced treefrog	–	+	+
2001–2002	<i>Hyla cinerea</i>	Green treefrog	+	+	+
2001–2002	<i>Hyla squirella</i>	Squirrel treefrog	+	+	+
GULN 2011–2017	<i>Hyla chrysoscelis/versicolor</i>	Cope's/grey treefrog complex	–	+	+
2001–2002	<i>Notophthalmus viridescens</i>	Eastern newt	+	–	+
2001–2002	<i>Pseudacris crucifer</i>	Spring peeper	–	–	+
2001–2002	<i>Lithobates clamitans</i>	Bronze frog	+	–	+

¹ This species was originally recorded as *Acris crepitans*, but more recent molecular studies use *A. blanchardi* for individuals west of the Mississippi river (see Gamble et al. 2008).

² This species was originally recorded as *Eurycea quadridigitata*, but more recent molecular studies classify individuals in the JELA area as *E. paludicola* (see Wray et al. 2018).

³*Pseudacris fouquettei* was originally listed as *P. triseriata* in the inventory, but the taxonomy has changed. Anything previously called *P. triseriata* in most of Louisiana, including JELA, is now referred to as *P. fouquettei* (see Lemmon et al. 2008).

⁴*Desmognathus valentinei* (when reported, it was *D. fuscus*) was included as a potential species for JELA by Anderson and Siegel (2003), but there were no observations during that study nor has it been seen in the park since. This species has recently been split from *D. auriculatus*, which occurs further to the east (Means et al. 2017).

Table B-2 (continued). JELA species checklist adapted from Anderson and Siegel (2003), with one addition from GULN's pilot work at the Barataria Preserve. The 11 species marked with a "+" in either of the first two columns were detected during the GULN pilot work in pipes or coverboards at that site (2011–2017). Of these detected species, only *Hyla cinerea*, *H. squirella*, *H. avivoca*, *Incilius nebulifer*, *Gastrophryne carolinensis* and *Eleutherodactylus planirostris* use artificial cover objects often enough for the GULN to monitor of their relative abundances. This conclusion is based on from the GULN pilot work at the Education Center site at JELA, which is described in detail in Carlson (2018). The 2001–2002 survey was by Anderson and Siegel (2003) and the 1988 survey was by Rossman and Demastes (1989). Taxonomic names in the table follow Crother (2017).

Survey when first detected	Species name	Common name	GULN board	GULN pipe	GULN casual or minnow trap
2001–2002	<i>Lithobates grylio</i>	Pig frog	–	–	+
2001–2002	<i>Lithobates sphenoccephalus</i>	Southern leopard frog	–	–	+
2001–2002	<i>Siren intermedia</i>	Lesser siren	–	–	+
1988	<i>Pseudacris fouquettei</i> ³	Cajun chorus frog	–	–	–
1988	<i>Lithobates catesbeianus</i>	American bullfrog	–	–	+
None	<i>Desmognathus valentinei</i> ⁴	Valentine's southern dusky salamander	–	–	–

¹ This species was originally recorded as *Acris crepitans*, but more recent molecular studies use *A. blanchardi* for individuals west of the Mississippi river (see Gamble et al. 2008).

² This species was originally recorded as *Eurycea quadridigitata*, but more recent molecular studies classify individuals in the JELA area as *E. paludicola* (see Wray et al. 2018).

³*Pseudacris fouquettei* was originally listed as *P. triseriata* in the inventory, but the taxonomy has changed. Anything previously called *P. triseriata* in most of Louisiana, including JELA, is now referred to as *P. fouquettei* (see Lemmon et al. 2008).

⁴*Desmognathus valentinei* (when reported, it was *D. fuscus*) was included as a potential species for JELA by Anderson and Seigel (2003), but there were no observations during that study nor has it been seen in the park since. This species has recently been split from *D. auriculatus*, which occurs further to the east (Means et al. 2017).

Table B-3. SAAN species checklist adapted from Durand (2004), with two addition species from GULN's pilot work. "Rancho only" means that species has only been documented at the Rancho de las Cabras, which is 40 miles south of San Antonio. "Missions only" means that the species has only been documented within the main Missions NPS property in San Antonio. The first five species marked with a "+" in the GULN coverboard or pipe columns are candidate species for long-term monitoring, based on detections from the Missions property during the pilot phase (2011-2017). Of these detected species, only *Eleutherodactylus cystignathoides* and *Incilius nebulifer* use GULN cover objects often enough to be monitored for relative abundances at the main Missions property (see Carlson 2018 for details). The 2003 survey was by Durand (2004). Although *Lithobates berlandieri* and *Hyla chrysoscelis/versicolor* were not found in that initial survey, they were listed by Durand (2004) as possible species on the park, based on the literature or museum specimens. Taxonomic names in the table follow Crother (2017).

Survey when first detected	Species name	Common name	GULN cover-board	GULN pipe	GULN casual obs.
2003	<i>Scaphiopus couchii</i> (Rancho only)	Couch's spadefoot toad	–	–	–
GULN 2011–2017	<i>Lithobates berlandieri</i>	Rio Grande Leopard Frog	+	–	–
2003	<i>Lithobates catesbeianus</i>	American Bullfrog	–	–	+
2003	<i>Eleutherodactylus cystignathoides</i> (Missions only)	Rio Grande chirping frog	+	–	+
2003	<i>Incilius nebulifer</i>	Gulf Coast toad	+	–	+
2003	<i>Acris blanchardi</i> ¹	Blanchard's cricket frog	–	–	+
2003	<i>Gastrophryne olivacea</i>	Western narrow-mouthed toad	+	–	–
2003	<i>Hyla cinerea</i>	Green treefrog	–	+	+
GULN 2011–2014	<i>Hyla chrysoscelis/versicolor</i> (Rancho only)	Cope's/gray treefrog complex	–	+	–

¹This species was originally recorded as *Acris crepitans blanchardi*, but more recent molecular studies use *A. blanchardi* for individuals west of the Mississippi river (see Gamble et al. 2008).

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The Department of the Interior protects and manages the nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its special responsibilities to American Indians, Alaska Natives, and affiliated Island Communities.

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