National Park Service
U.S. Department of the Interior
Natural Resource Stewardship and Science

Monitoring Terrestrial Vegetation in Gulf Coast Network Parks

Protocol Implementation Plan

Natural Resource Report NPS/GULN/NRR—2018/1746

ON THE COVER
Photographs of the diverse vegetated habitats of parks and preserves in the Gulf Coast Network. Clockwise from upper left: Jean Lafitte National Historical Park and Preserve, Palo Alto Battlefield National Historical Park, Natchez Trace Parkway, Gulf Islands National Seashore, San Antonio Missions National Historical Park, and Big Thicket National Preserve.
Photographs courtesy of the National Park Service.

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This report received formal peer review by subject-matter experts who were not directly involved in the development or pilot implementation of the project. Peer review was conducted by highly qualified individuals with subject area technical expertise and was overseen by a peer review manager.

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Change History

Version numbers are 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 are 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.

Revision Date	Author	Changes Made and Justification	New Version #

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Executive Summary

The Gulf Coast Network conducts long-term terrestrial vegetation monitoring in eight National Park units as part of the nationwide Inventory and Monitoring Program of the National Park Service. Park plant communities are monitored as key vital signs or ecological indicators because they create the food and habitat upon which many other species depend, and because changes in their condition often reflect the effects of stressors such as fire, extreme weather, disease, invasive species, and land-use change. Monitoring plant communities over time can provide critical insights into ecosystem health by revealing the key players in a relatively undisturbed system and documenting the consequences of anthropogenic change.

Terrestrial vegetation monitoring in network parks takes place in 214 permanently-marked plots that are randomly located within naturally vegetated areas the following eight national park units: Jean Lafitte National Historical Park and Preserve (JELA); Palo Alto Battlefield National Historical Park (PAAL); Natchez Trace Parkway (NATR); Gulf Islands National Seashore (GUIS); Padre Islands National Seashore (PAIS); Vicksburg National Military Park (VICK); San Antonio Missions National Historical Park (SAAN); and Big Thicket National Preserve (BITH). Each park has between 10 and 56 plots, scaled for the size of the park or focal park unit. Monitored habitats include semi-arid scrublands, coastal vegetated dunes, prairies, pine savannas, upland forests, marshes, and swamps. Plots are 20 × 20 meters in size, and within these plots data are collected on species richness, per-species coverage, per-species frequency and several forest-related metrics. All adult trees are identified to species and marked with a unique ID number, and their diameter at breast height (DBH) and condition are tracked over time. Site condition and other environmental covariates are also recorded.

The Gulf Coast Network's approach, rationale and required resources for terrestrial vegetation monitoring are described in this document, the Protocol Implementation Plan Narrative. The 11 associated Standard Operating Procedures (SOPs) provide detailed instructions on how to collect, manage, analyze and disseminate the project's findings. The network's narrative and SOPs are derived, in large part, from the Northeast Temperate Network's forest monitoring protocol. The difference in approach between the two networks is documented throughout the Gulf Coast Network's narrative and SOP documents.

Section 1. Introduction

Background

Plant communities are a defining component of terrestrial landscapes. They provide food, habitat, and shelter for humans and wildlife, and they are essential to ecosystem function by sequestering carbon, producing oxygen, removing pollutants from the land and water, stabilizing soil and shorelines, and reducing storm energy and impacts. Plant communities can ameliorate the damage caused by natural or anthropogenic events, but they may also be changed in the process. The composition, cover and structure of a local flora reflect both the natural environment—in its current and historic form—and the impacts of stressors. In shorter timeframes (one to several years), changes in vegetation may be linked to abrupt events, such as fires, coastal storms, and onset of disease. In the longer term, shifts in species' ranges, distributions, and local abundances may serve as indicators of climate change. Monitoring plant communities over time can therefore provide critical insights into ecosystem health, by revealing the key players in an undisturbed system and documenting the consequences of anthropogenic change.

Vegetation monitoring is used extensively by the National Park Service (NPS) to help preserve National Park resources "unimpaired for future generations (National Park Service Organic Act of 1916)." Within the NPS, there are 32 networks engaged in monitoring activities as part of the Inventory and Monitoring Division (IMD). The Gulf Coast Network (GULN) is in the Southeast Region of the IMD, and serves eight parks from Florida to Texas: Jean Lafitte National Historical Park and Preserve (JELA); Palo Alto Battlefield National Historical Park (PAAL); Natchez Trace Parkway (NATR); Gulf Islands National Seashore (GUIS); Padre Islands National Seashore (PAIS); Vicksburg National Military Park (VICK); San Antonio Missions National Historical Park (SAAN); and Big Thicket National Preserve (BITH). Like the other I&M networks, the Gulf Coast Network monitors the "overall health or condition of park natural resources" through a representative subset of park processes and elements called Vital Signs (Fancy et al. 2009). In April 2005, the Gulf Coast Network convened with park leadership and stakeholders to prioritize among 42 vital signs that had previously been identified as relevant to network parks. As described in the approved GULN monitoring plan (Segura et al. 2007), several vegetation-related elements were among the 19 vital signs that the participants deemed highest priority: nonnative vegetation, salt marsh plant communities, freshwater wetland communities, riparian communities, forest health, and terrestrial vegetation. Collectively, these communities and elements can be combined into one functional network vital sign: Terrestrial vegetation. This plan outlines the means by which the Gulf Coast Network collects, manages, and reports monitoring data for its terrestrial vegetation vital sign, thus addressing a range of terrestrial vegetation attributes across all network parks.

Vegetation in Gulf Coast Network Parks

The Gulf Coast Network spans several different ecoregions across much of the southeastern and South Central United States (Figure 1). As such, the eight GULN parks encompass diverse vegetation resources, including:

- Dune-face scrub, grasslands, and wetlands of the barrier islands (Figure 2A);

- Marshes (salt to freshwater), cypress/tupelo swamp forests, bottomland hardwood forest, coastal hardwoods and pines, wet to dry pine savannah (Figure 2B), and lowland riparian corridors characteristic of the Central Gulf Coast;
- Pine forests, hardwood forests and mixed forests of Mississippi, Alabama, and lower Tennessee (Figure 2C);
- Mixed lowland and slope forests of East Texas;
- Riparian woodland corridor, scrub and grasslands of the San Antonio River Valley; and
- Salt-prairie grasslands and Tamaulipan thorn-scrub of the South Texas Coastal Plain (Figure 2D).

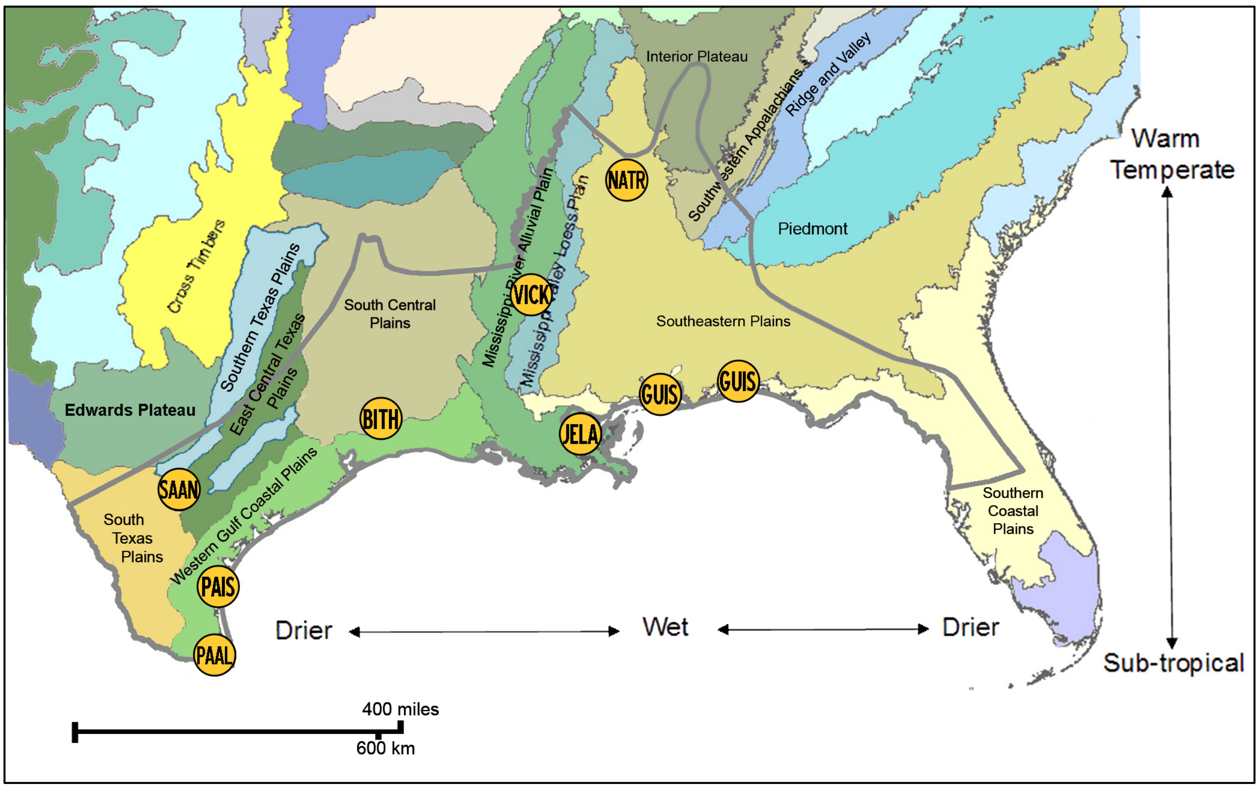

Figure 1. Park locations and ecoregions of the Gulf Coast Network. Adapted from the 2003 U.S. Environmental Protection Agency Level III Ecoregions of the Continental United States (revision of Omernik 1987). The heavy gray line indicates the boundary of the Gulf Coast Network. Yellow circles indicate the location of the eight parks in the network. For NATR, the circle indicates the park's head office, although the actual parkway spans from Natchez, Mississippi, to near Nashville, Tennessee. For GUIS, the park has sections in Florida and Mississippi, but the head office is in Florida.

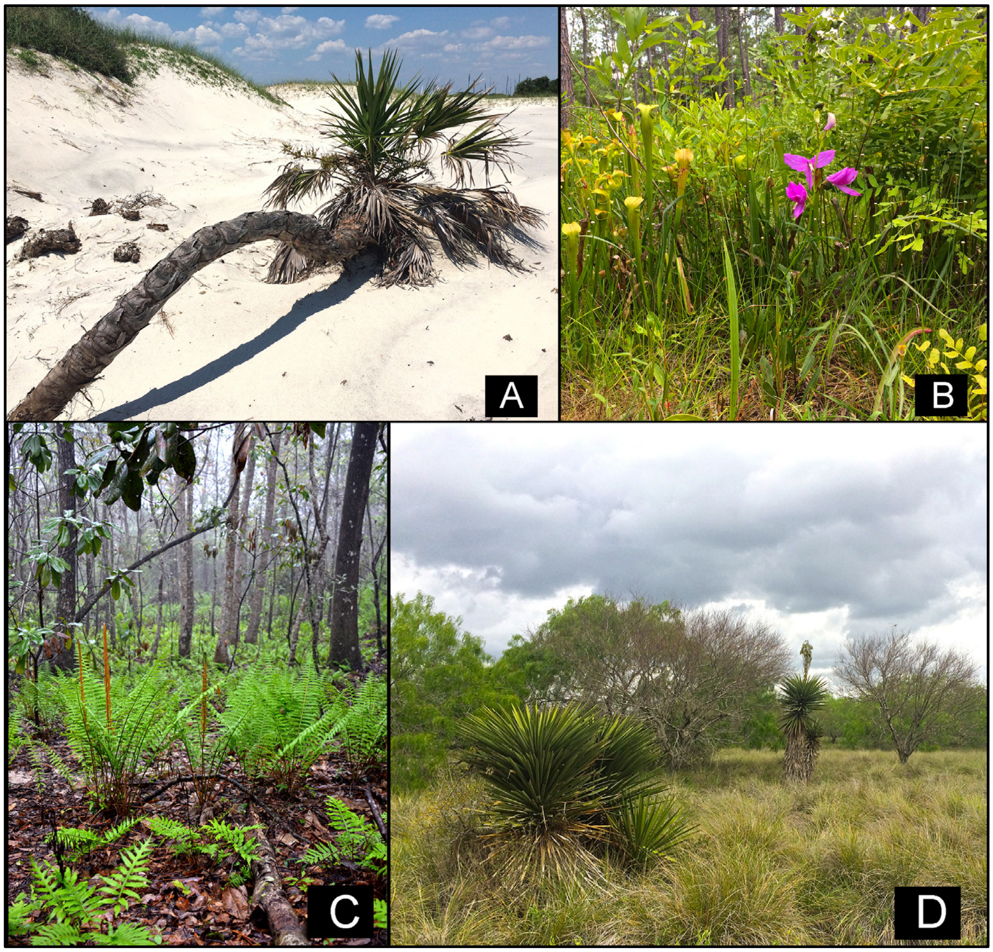

Figure 2. Some of the diverse plant community types of Gulf Coast Network Parks. (A) Grass-covered dune on Horn Island, Mississippi; (B) pine savannah wetland near Kountze, Texas; (C) mixed hardwood forest in Mississippi; and, (D) salt-prairie grassland intermixed with thornscrub in Brownsville, Texas.

Among the GULN parks, there are differing degrees of emphasis on cultural versus natural resources. The two national seashores (Gulf Islands and Padre Island) and two national preserves (Big Thicket and Jean Lafitte) are larger natural resource parks with substantial representation of regional and coastal plant communities. These four parks include relict examples of now-rare and vanishing habitats. In contrast, the remaining four parks, Natchez Trace Parkway, Palo Alto NHP, San Antonio Missions NHP, and Vicksburg NMP, have a historical and cultural focus, and they host smaller contiguous vegetation units that are sometimes extremely altered. Preservation of habitats and vegetation resources and the associated biodiversity are core elements in the enabling legislation of Big Thicket National Preserve, Jean Lafitte NHP&P, and Padre Island NS. For additional details on the parks, their cultural and natural resources and their vegetation communities, see Segura et al. (2007).

Source Protocol and How It Was Modified

The Gulf Coast Network monitors terrestrial vegetation following a version of the peer-reviewed and approved *Long-term Forest Monitoring Protocol* in use by the Northeast Temperate Network (NETN; Tierney et al. 2016). All NETN standard operating procedures (SOPs) were reviewed, modified, and edited as necessary by the Gulf Coast Network to ensure network relevance and integrity across all SOPs. Major changes were made to the sampling design, plot layout (Figure 3), and field methods, primarily to accommodate the diverse and varied vegetation communities of the Gulf Coast region.

There are eight major changes made to the NETN protocol:

1. Monitoring objectives—The Gulf Coast Network reduced the number of objectives and changed their wording, but all objectives remain closely related to NETN objectives.

2. Spatial sampling frame—The Gulf Coast Network includes all naturally-vegetated habitats in parks or target units, rather than forests and woodlands only.

3. Selection of plot locations—The Gulf Coast Network uses a simple random draw within polygons rather than Generalized Random Tessellation Stratified (GRTS) sampling.

4. Timing of sampling—The Gulf Coast Network field season is longer, and repeat sampling of plots is on a three-year cycle rather than four.

5. Sampling crew logistics—The Gulf Coast Network will staff one team per year, rather than two.

6. Plot design and sampling methods—See Figure 3 and GULN SOP VEG06 *Vascular Plant Species Presence, Cover, and Abundance* (Carlson and Segura 2018a).

7. Four SOPs were removed.

8. Analysis and reporting: The Gulf Coast Network does not produce an ecological integrity scorecard and has developed its own data analysis and reporting SOP.

These eight changes are explained in depth in Section A of the Supplemental Materials packet (Carlson et al. 2018b). This supplemental document also includes added justifications for several of the most substantial changes. Descriptions of specific modifications plus minor procedural modifications are also provided in each GULN SOP.

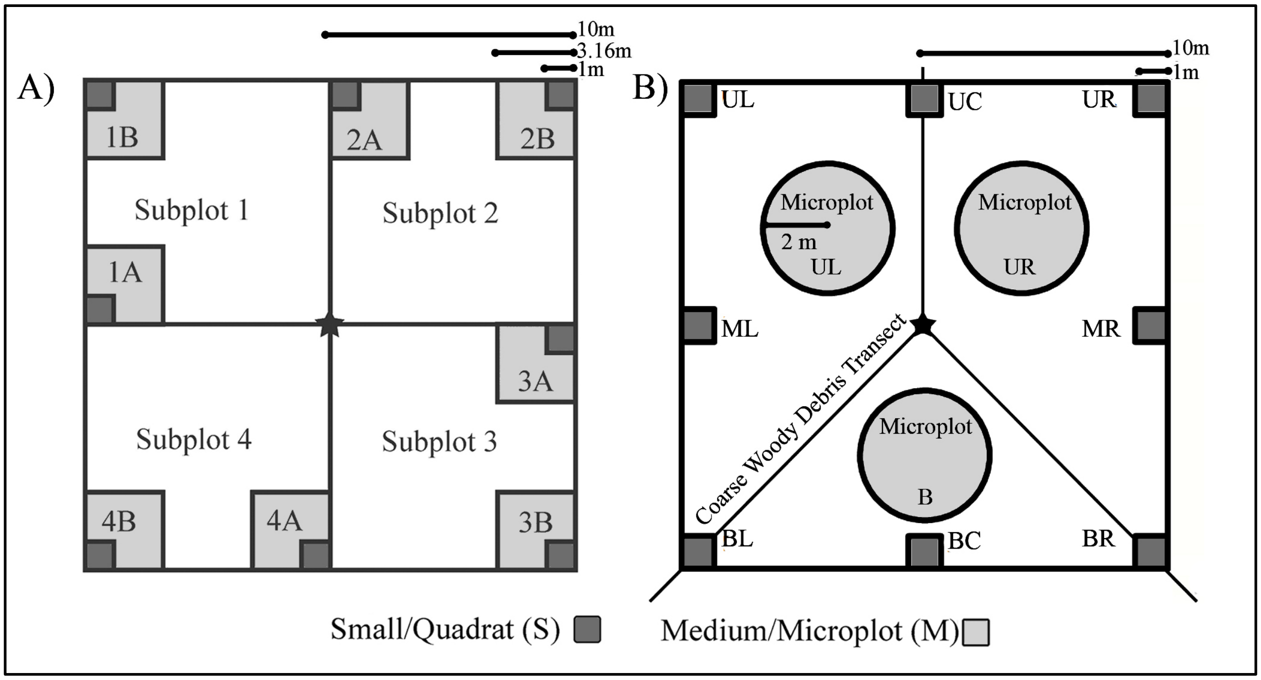

Figure 3. Plot designs for long-term vegetation monitoring. (A) The design of the vegetation sampling plot for Gulf Coast Network, which is a modified version of (B) the vegetation sampling plot for the Northeast Temperate Network. In (A), the eight 1 x 1 meter units are called quadrats, with names 1A-S, 1B-S, 2A-S, 2B-S, 3A-S, 3B-S, 4A-S, and 4B-S. The eight 3.16 x 3.16 meter units are called microplots, with names 1A-M, 1B-M, etc. The four 10 x 10 meter units are called subplots and the full 20 x 20 meter unit is called the whole plot.

Section 2. Conceptual Framework for Monitoring

Vegetation communities create the food and habitat upon which many other species depend. As such, stressors that affect plants will also affect the local fauna and landscape as a whole, which can ultimately degrade the park's overall value to the public—for example, through the loss of charismatic mammals, birds, and pristine, scenic terrains. By monitoring plant communities, this protocol implementation plan can document the potential impacts of several key stressors that affect whole-park integrity (Table 1). Focal issues and stressors for parks include the expansion of invasive species, an increase in natural and anthropogenic disturbance (e.g., frequency or intensity of coastal storms, fire suppression, impacts from adjacent land-use and development), and changes in weather patterns and climate (e.g., droughts, global climate change). Unfortunately, multiple stressors are often acting concurrently, which makes it difficult to identify the cause of any given shift in plant community composition or coverage. By simultaneously measuring key stressors (or their proxies) and the plant communities likely to be affected, Gulf Coast Network staff have a better chance of identifying the specific driver of change. This, in turn, will provide insights that resource managers can use to mitigate stressor effects at multiple spatial and temporal scales.

Specific Threats to GULN Park Vegetation Resources

Network parks exist in close proximity to developed agricultural and urban areas, which can detrimentally affect park vegetation in several ways. Adjacent land use changes can impact plants in parks through altered hydrology, chemical pollution from waste materials, and application of fertilizers and pesticides. Recurrent introduction of exotic or invasive plants and animals is also a serious threat to all GULN parks. Major invasive plants include chinaberry (*Melia azedarach*), Chinese tallow (*Triadica sebifera*), kudzu (*Pueraria lobata*), Japanese honeysuckle (*Lonicera japonica*), Brazilian peppertree (*Schinus terebinthifolius*), privet species (*Ligustrum* spp.) and numerous forbs and grasses. In addition to invasive plants, invasive animals like feral hogs (*Sus scrofa*) can severely damage park vegetation, as can a wide range of invertebrate pests and pathogens. Vegetation monitoring by the network addresses these threats by documenting hog damage within plots, recording change in frequency and coverage of invasive plants, and monitoring tree condition for unusually high herbivory or pathogen attack. Other monitoring initiatives provide data on adjacent land-use and development that can be linked to changes in plant communities within parks (Table 1).

Gulf Coast Network parks can also be severely impacted by natural phenomena, such as coastal storms, drought, hurricanes, and tornadoes. Extreme weather events can lead to flooding, saltwater intrusion, canopy defoliation, and tree blowdown, which have negative consequences for park vegetation. Texas parks (Big Thicket National Preserve, Palo Alto Battlefield NHP, Padre Island NS and San Antonio Missions NHP) have also experienced several severe droughts since 2011, which may have lasting impacts on vegetation communities. This protocol implementation plan provides a means of documenting the impacts of extreme weather events by monitoring changes in canopy closure, tree growth and species coverage, which can be linked to weather, hydrologic and topographic data collected through other monitoring initiatives (Table 1).

Two additional stressors receive specific attention through the GULN terrestrial vegetation monitoring effort: fire suppression/fire management application and climate change (Table 1). For the former stressor, park-wide data on the fire management activities (both historic and current) can be linked to each site's current vegetation community and vegetation change over time. For example, fire suppression in parks like Big Thicket National Preserve and Palo Alto Battlefield NHP may enable encroachment and/or overgrowth of woody vegetation on what should be natural grasslands or sparsely-wooded savannas. For the latter stressor of climate change, cross-decade monitoring efforts are essential for documenting trends. Although certain geographic areas may already be detectably hotter and drier, any associated changes in plant communities' or species' ranges will likely occur more slowly.

Table 1. Factors affecting terrestrial vegetation resources within Gulf Coast Network parks and potential measures for vital signs monitoring. Asterisks indicate potential measures that have been selected for inclusion in the GULN vegetation monitoring effort. 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 plant species enter parks across all boundaries and displace native species and communities. Introductions occur from non-native and ornamental plantings and weed populations in adjacent agricultural and urban lands. Invasive animals or insects can also harm native vegetation. All GULN parks have diverse invasive species challenges. A related concern is native species that have artificially high abundances due to human activities, and therefore cause harm like invasive species. On such example is the white-tailed deer, which causes serious damage to forests in more northern parks.	Invasive species richness*, coverage* and frequency*; changes in detection rate of invasive species over time*; change in native species richness/coverage with increasing richness/coverage of invasive species*; park-based monitoring of invasive species; NPS EPMT effects monitoring; GULN LiDAR sampling to measure mid-story height and density (e.g., to detect patches of *Ligustrum sinense* in NATR); NGO research efforts.
Adjacent Land Use and Development	Urban expansion, residential and commercial land conversion, and highway construction are increasing in areas surrounding most GULN parks. Land conversion in adjacent areas results in parks becoming relict habitat islands under threat from diverse human impacts.	Changes in plant species coverage* and frequency*; changes in detection rate of invasive species over time*; changes in plant community composition*; GULN Adjacent Land Use monitoring that tracks changes in local and regional development; water-quality monitoring; USGS hydrological projects/studies.
Extreme Weather Events	Low-elevation coastal wetlands and island vegetation are vulnerable to storm surges. Similarly, canopy forests are vulnerable to storm winds. Plants may be increasingly impacted by these events over time because, as global climates change, coastal storms are forecasted to shift in frequency, magnitude, and duration.	Canopy closure*; tree DBH*; tree mortality and regeneration*; changes in plant species coverage*; storm frequency; storm magnitude; shoreline displacement; coastal topography; use of LiDAR data, including canopy height, porosity, and comparative model change.

Table 1 (continued). Factors affecting terrestrial vegetation resources within Gulf Coast Network parks and potential measures for vital signs monitoring. Asterisks indicate potential measures that have been selected for inclusion in the GULN vegetation monitoring effort. The remaining listed measures are addressed through other monitoring initiatives by NPS or partners.

Stressor Category	Issue for the Park	Potential Measures
Fire Suppression and Fire Management Application	Many GULN parks have active prescribed-burn programs for vegetation management and restoration. Other parks and areas reflect a history of fire-suppression. Both activities result in changing vegetation on parks and increasing need for information about impacted resources.	Richness*, coverage* and frequency of native and invasive species*; tree mortality and regeneration*; canopy closure*; LiDAR datasets – canopy height and porosity; park fire programs and fire effects monitoring; NGO research.
Climate Change	Anticipated long-term climate change is predicted to alter both species' ranges and community composition at GULN parks. Rising sea levels will impact lower coastal wetlands and island flora. Changing precipitation and mean temperature patterns are expected to alter vegetation communities in hotter and drier areas.	Changes in plant species richness*, coverage* and frequency*; vegetation composition*; ; tree mortality and regeneration*; canopy closure*; LiDAR datasets – canopy height and porosity; park DEM data; vegetation mapping; NGO research; long-term meteorological data (temp, precip) from nearby locations

Section 3. Measurable Objectives

This protocol is implemented to monitor status and trends in the structure, function and condition of vegetation communities in GULN parks, with the goal of informing management decisions affecting those systems. There are four primary monitoring objectives for this protocol implementation.

1. Determine status and trends of vascular plant species richness in whole parks (VICK, JELA and PAAL) or targeted areas of the parks (GUIS, PAIS, SAAN, BITH, and NATR), using 400 square-meter (431 square feet [ft^2]) long-term plots. Species composition includes native and nonnative species as encountered.

2. Determine status and trends in the percent cover of vascular plant species in whole parks or targeted areas of the parks, using 1 square-meter quadrats and 10 square-meter microplots, nested within the 400 square-meter long-term plots. The focal vascular plants for this objective are herbs, subshrubs, shrubs, seedlings and saplings, as well as low-growing lianas, vines and epiphytes.

3. Determine status and trends in the relative frequency of vascular plant species in whole parks or targeted areas of the parks, using nested frequency data for 1 square-meter (10.8 ft^2), 10 square-meter (107.6 ft^2) or 100 square-meter (1,076 ft^2) sampling units, nested within the 400 square-meter long-term plots.

4. For forested plots (canopy cover greater than 25%), determine the status and trends in canopy closure, basal area, tree mortality, and stem density for all tree species greater than or equal to 10 centimeters (3.9 inches [in]) DBH combined, and determine the status and trends in tree growth (DBH), tree mortality, tree condition and tree regeneration on a species-by-species or focal-group basis, in whole parks or targeted areas of the parks, using 10 square-meter and 400 square-meter long-term plots.

Section 4. What's Being Measured and How?

The Gulf Coast Network monitors terrestrial vegetation in fixed plots that are resampled once every three years. Gulf Coast Network plots were selected using a randomized sampling design based on whole-park polygons (three of eight parks) or polygons around targeted units within parks (five of eight), with roads, paved surfaces, waterbodies, and boundary buffers excluded in advance. The GULN protocol uses, with some modification, the field sampling methods that were developed by the Northeast Temperate Network and have been approved for implementation (Tierney et al. 2016). The links between monitoring objectives, sampling methods and data outputs are provided in Table 2. Figure 4 presents the four focal objectives in a schematic diagram.

Table 2. Monitoring objectives, sampling methods, and resultant data for the GULN Terrestrial Vegetation Monitoring Protocol.

Objective	Sampling Method	Data Collected
Status and trends in vascular plant species richness	Count the number of vascular plant species encountered in eight 1 m^2 (1 x 1 m) quadrats, eight 10 m^2 (3.16 x 3.16 m) microplots, and four 100 m^2 (10 x 10 m) subplots. The data from the four subplots can be combined to encompass the full 400 m^2 (20 x 20 m) plot.	The total count of species in a sampling unit is species richness. Data can be summarized as averages across quadrats, microplots, subplots, or simply the total count for the 400 m^2 plot. There are separate counts of native species and invasive species. Other plant subsets may also be counted separately.
Status and trends in percent cover of vascular plant species	Estimate percent cover for all species in each of eight 1 m^2 quadrats, up to 1.5 meters above the ground. Cover is additionally recorded for all non-tree species in four 10 m^2 microplots per 400 m^2 plot. In the microplots, lianas, vines and epiphytes are included up to 2 meters high.	Percent cover is estimated on a continuous scale from 0-100% for each species rooted in, overhanging or otherwise present in eight 1 m^2 quadrats or four 10 m^2 microplots per plot. The appropriate scale of measurement (quadrat or microplot) is selected for each species, and only one scale is used in analyses. Coverage of each species can be averaged over those four or eight sampling units or kept separate for trend analyses. Species can be analyzed individually (if relatively common) or as plant guilds, e.g., native or non-natives, shrubs, graminoids, forbs, or vines/lianas.
Status and trends in relative frequency of vascular plant species	Record nested frequency by documenting species occurrence in the eight 1 m^2 quadrats, eight 10 m^2 microplots, and four 100 m^2 subplots per 400 m^2 plot.	For each plot, relative frequency can be estimated at three scales per species. At the largest scale, the frequency is the number of 100 m^2 subplots that contain at least one member of that species, and then dividing that by four. For the 10 m^2 microplots or 1 m^2 quadrats, it is the number of sampling units with at least one member of that species, divided by eight. Only one frequency estimate is used for each species: the smallest plot size for which 20-80% of same-sized plots are occupied.

Table 2 (continued). Monitoring objectives, sampling methods, and resultant data for the GULN Terrestrial Vegetation Monitoring Protocol.

Objective	Sampling Method	Data Collected
Status and trends in canopy closure, basal area, stem density and mortality across species. Within species or focal groups, status and trends in tree growth (DBH), tree mortality, tree condition, and tree regeneration and recruitment. Qualitative photopoints	Record canopy closure, DBH and condition of tagged trees ≥10 cm in the 400 m^2 plot, and count tree seedlings and saplings in 10 m^2 microplots. Take photopoint photos in the 400 m^2 plot.	Canopy closure is estimated once for the entire plot, without separating by species. Basal area is calculated from DBH of individual trees and then summed across all trees or tree subsets. Stem density is a count of trees per plot, with and without separating by species. Tree mortality is calculated both within and across species, as the number of newly dead trees since the last visit divided by the sum of alive plus newly dead. For each species or for focal groups, several plot-wide averages can be calculated: DBH, seedling count and sapling count in four size classes and other standard metrics of regeneration and recruitment. The DBH and condition of individual trees can also be tracked over time. Photopoints are for illustrating qualitative change.

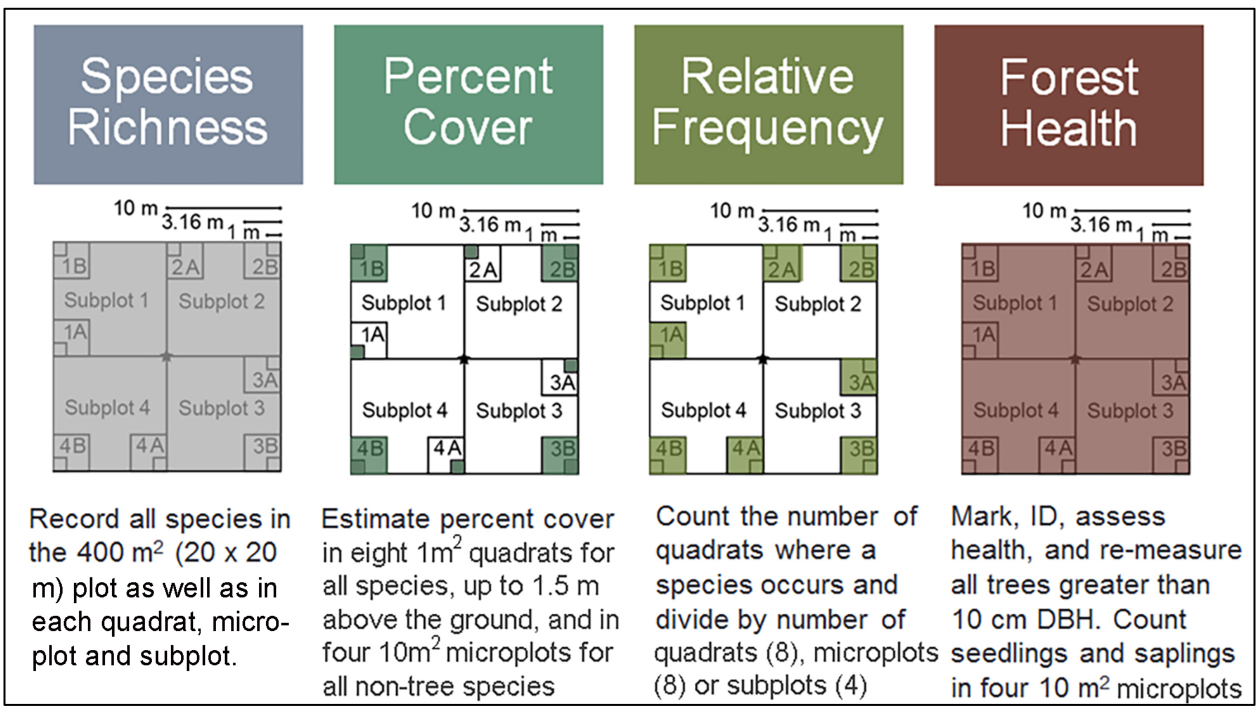

Figure 4. The monitoring objectives and data types of the Gulf Coast Network Terrestrial Vegetation Monitoring Protocol. For parks that have no plots with tree canopy cover >25%, the forest health methods and objectives do not apply.

Overview of Methods

Preparation and Plot Set-Up

The crew prepares for each field season and field trip well in advance following the steps detailed in GULN SOP VEG02 *Preparation for Sampling and Equipment List* (Carlson and Segura 2018b). All plots within a given park are visited on single trip or set of consecutive trips for that season, in coordination with park management. On the first visit to each permanent 20 × 20 meter (65.6 × 65.6 ft) plot, the crew uses GPS units and maps to navigate to a pre-selected plot center-point. This point is marked with rebar, and then its location is recorded on-site using a high-accuracy GPS (e.g., Trimble Geo 7X with sub-meter postprocessing accuracy for an open canopy). The sampling crew locates and places the remaining eight permanent markers using a rangefinder, and if necessary, with measuring tapes and a compass. The plot layout is shown in Figure 3. These and related methods are described in GULN SOP VEG03 *Site Selection, Plot Establishment and Return Visits* (Carlson et al. 2018a).

Field Sampling Methods

On every sampling visit to a plot, the field crew completes three major tasks, with each task associated with its own datasheet: (1) site measurements, (2) tree measurements, and (3) vascular plant species presence, cover and abundance. For the first task, the crew records disturbances to the plot, canopy closure, flooding and wetland status indicators (see GULN SOP VEG04 *Site Measurements* [Carlson and Segura 2018c]). They also take six photopoint photographs for the plot, as prescribed in the GULN SOP VEG07 *Photopoint* (Carlson and Segura 2018d). Data are recorded on VEG. FORM (1) Site Measurements (see Section D of the Supplemental Materials packet; Carlson et al. 2018b).

For the second main task, the field crew tags and identifies all trees within the 20 × 20 meter plot that are greater than 10 centimeters (3.9 inches) DBH. For these trees, they record the diameter-at-breast-height (DBH) and their status (i.e., alive, dead, leaning, fallen, broken) and condition (e.g., decay, insect damage, foliage damage). The numbered metal tags are nailed 10 centimeters (3.9 in) below the DBH measuring point, which means the tag is placed at 1.27 meters (4.16 ft) above the ground level. GULN SOP VEG05 *Tree Measurements* (Carlson and Segura 2018e) provides specific details about what data are recorded, as well as instructions for how to deal with forked trees or trees that otherwise require a different DBH measurement. Data are recorded on VEG. FORM (2) Tree Measurements (see Section D of the Supplemental Materials packet; Carlson et al. 2018b).

For the third main task, the field crew begins by recording nested frequency of each species and estimating the percent cover of each species in quadrats and microplots. For nested frequency, a pair of observers starts by listing all plant species that are rooted within, prostrate across or overhanging at any height the 1 × 1 meter (3.28 × 3.28 ft) quadrat in corner 1A-S (see Figure 3). Next, they estimate percent cover for each species in that quadrat, based all on foliage and stems for that species, but only up to 1.5 meters above ground level. Then they step back to survey the 1A-M microplot (3.16 × 3.16 meter [10.36 × 10.36 ft]), adding any new species rooted in, prostrate across or overhanging that microplot, again at any height including canopy level. Next, they move to the 1B-S quadrat, and they record species and estimate cover as for 1A-S. Then they step back to survey the 1B-M microplot, listing all new species as for 1A-M. Also on 1B-M, the crew estimates percent cover of non-tree species, which is a step performed on all B microplots but none of the A microplots. These percent cover estimates consider each non-tree species separately, and they include vines, lianas and epiphytes only up to 2 meters above ground level. The remaining non-tree species have no height cutoff for % cover in microplots. Finally, the crew surveys the remainder of subplot 1 (10 × 10 meter [32.8 × 32.8 ft]) and add any additional species rooted in, overhanging or prostrate across it. The crew then moves to subplot 2 (and so forth) and repeats these steps. Unlike for much of the GULN protocol, the nested frequency procedures do not follow a NETN SOP, but are instead based on the National Wetland Conditions Assessment Field Operations Manual (USEPA 2016). For both quadrat and microplot percent cover data, estimates are made on a continuous scale with 1% increments acceptable (also following USEPA 2016).

The third task has an additional component of counting seedling and saplings within four of 3.16 × 3.16 meter microplots. The field crew members simply count for each species the number of seedling into two size classes (30-100 centimeters [cm] and 100+cm with DBH <1 cm), number of small saplings (1to 5 cm DBH [0.4-2 inches]) and number of large saplings (>5 to <10 cm DBH [>2 to <3.9 inches]) that are rooted within each microplot. Full instructions are provided in GULN SOP—*VEG06 Vascular Plant Species Presence, Cover and Abundance* (Carlson and Segura 2018a). Data are recorded on VEG FORM (3) Vascular Plant Species Presence, Cover and Abundance (see Section D of the Supplemental Materials packet; Carlson et al. 2018b).

Data Entry and Management

Field data are recorded on paper datasheets. As soon as possible after field work, data are entered into the GULN vegetation database following the GULN In-House Document: Data Entry. Data management steps and QA/QC procedures are listed in GULN SOP VEG09 *Data Management and Quality Assurance/Quality Control* (Carlson et al. 2018c). See also Section 6 Data Management, Analysis, and Reporting, further below.

Data Analysis and Reporting

The Gulf Coast Network creates a Vegetation Monitoring Event and Status Report after one field season is completed for each park (once every three years). This report includes text, figures, tables, and summary statistics. After three rounds of data collection in a park, the network completes a 'Status and Trends in Vegetation' report, which includes cross-year trend analyses using linear or generalized linear mixed models. For some metrics, species are analyzed separately for change over time, but for others, species are grouped and analyzed together. Generalized models are used for some variables, 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 the statistical package lme4 (R Core Team 2014; Bates et al. 2015). Focal variables for each park-wide sampling event and cross year comparisons (i.e., evaluating possible change in derived variables over time) include species richness, species frequency, species or guild coverage estimation, canopy closure, basal area, stem density, mortality rate, tree growth in terms of DBH, seedling and sapling abundance, and tree condition. After the first Status and Trends report, the network re-analyzes trends no less frequently than once per three sampling events, with the expectation that subsequent reporting can be even more frequent, to meet park-specific needs and interests. Data analysis and reporting procedures are provided in GULN SOP VEG10 *Data Analysis and Reporting* (Carlson 2018). See also Section 6 Data Management, Analysis, and Reporting, further below.

Additional Operational Implementation Notes

Island units at Gulf Islands NS require transport of field teams to sites by boat. Boat transportation is provided by the park. Access to some marsh areas at Jean Laffite NHP&P requires airboat support; airboat transportation is provided by the park. Access to Padre Island NS and some sites at Big Thicket National Preserve may involve extended cross-country travel; travel may require UTV, which may be available from the park or be procured from commercial or other sources as needed.

Most network parks have indicated strong interest in participating in the Gulf Coast Network's terrestrial vegetation sampling when park staff members are available, and such participation may greatly enhance efficiency and shorten overall sampling time. As participation is not a park obligation (except for some transport, as described above), the GULN sampling schedule is developed annually under the expectation that GULN staff or contractors/collaborators complete all field work on their own.

Section 5. Sampling Design and Monitoring Schedule

Spatial Allocation

The Gulf Coast Network allocates 10–56 plots per park, which are distributed as a random draw across 1–5 focal polygons per park and 4–18 plots per polygon **(**Table 3; for maps of plot locations see Section B in the protocol Supplemental Materials packet; Carlson et al. 2018b**)**. These polygons represent entire parks or units, excluding roads (paved or unpaved), other paved surfaces, buildings, waterbodies, and a 50-meter (164-ft) buffer around infrastructure and park boundaries, to reduce the likelihood of plot disturbance by humans. A 25-meter (82-ft) buffer is used for San Antonio Missions NHP due to its small size. Plots are not spatially stratified within units, but they are required to be at least 250 meters (820 ft) apart. Across all eight parks, this amounts to sampling 214 plots over a two-year interval: 105 plots in sampling panel/year 1 and 109 in sampling panel/year 2. Four parks are allocated 30–32 plots each, two parks are allocated 10 plots each, and of the two remaining parks, one is allocated 11 and the other 56. Although most parks are divided into multiple polygons, these divisions are often based on boundaries between units and may not represent different vegetation communities. To maintain a realistic sampling effort in some of the larger parks, some lower-priority units are left unrepresented, although they are still of monitoring interest. In cases where parks wish to include those polygons through their own means, network staff will train park staff and use their data in analyses of status and trends, assuming consistency in sampling schedules, methods and QA/QC procedures.

The total number of 214 plots over two years was partially set by time and cost constraints for the Gulf Coast Network. Working within that upper ceiling, the Gulf Coast Network allocated plots among parks based on two factors**. First, plot allocation was scaled according to size.** Plots were distributed such that smaller parks had fewer plots than larger parks (range: 10–32, excluding BITH at 56; Table 3). If there were multiple high-priority polygons in a park, each polygon was assigned four to 12 plots, scaled according to polygon size (Table 4). The upper limit of 12 plots per polygon (or 18, for one park) was selected to match the network's available time and resources, and scaling rules aimed for coverages between 0.5 and 25 plots per 100 hectares, which was achieved for all but the three largest polygons. The only park that was allocated more than 12 plots in a unit was Jean Lafitte NHP&P, which requested more intensive coverage of their forested habitats. For more details, see Section B in the Supplemental Materials packet (Carlson et al. 2018b).

With a range of 10–32 plots per park (excluding BITH at 56), the GULN approach is generally consistent with the NETN protocol, with the exception that the NETN only samples forests and woodlands, and the GULN protocol can potentially include any natural habitat within a park. The NETN allocated 10–32 plots per park excluding Acadia NP at 176 (total of approximately 88 plots/year; Tierney et al. 2016). A similar range of sample sizes are seen in the vegetation monitoring protocols of the Cumberland Piedmont Network (CUPN) and the Southeast Coast Network (SECN). The CUPN protocol only samples forests and woodlands, and it allocated 16 plots per small park and 32 plots per large park for a total of 112 plots per year. The SECN protocol covers all habitat types, and it allocates between 4 and 30 plots per park, scaled according to park size, for a total of 103–124 plots per year.

Second, plots were allocated in accordance with NETN park and polygon minimums. The Northeast Temperate Network allocated no fewer than 10 plots per park, so the Gulf Coast Network sought to maintain the same effort (Table 3). Using power analysis, the Northeast Temperate Network has shown that the 10-plot park met targets for detecting change in several key metrics, and it did not necessarily perform worse than parks with slightly larger sample sizes (Miller and Mitchell 2014). For the Gulf Coast Network, a preliminary power analysis based on publicly available monitoring data in Jean Lafitte NHP&P suggested that six or even four plots provided sufficient power for detecting a 40% change in three of the five vegetation metrics that were available from that data set (more details below; full description of the GULN power analysis in Section C of the Supplemental Materials packet; Carlson et al. 2018b). Based on these findings, a minimum of four plots per polygon was set for the Gulf Coast Network. It is important to note, however, that the data used for the GULN power analysis came from plots that were relatively close to each other and in the same habitat type. For GULN parks or units that include plots in different habitat types, variability will likely be higher and the power to detect trends will thereby be lower. In consideration of this challenge, the network may perform trend analyses on each habitat type separately for a park, with the requirement that there be at least four plots in that habitat type for analyses to be performed. The current minimum of four plots per polygon and per habitat type will be re-assessed in subsequent power analyses on a broader geographic scale, following the first two rounds of data collection in all GULN parks.

Table 3. Acronyms, names, sizes, habitat types and plot allocation of parks within the Gulf Coast Network of the National Park Service. Asterisks indicate the three parks for which sampling points are essentially distributed throughout the entire park, excluding any manicured lawns, waterbodies, buildings, roads (paved or unpaved) and other paved areas. Each park's sampling polygon also had a 50 meter buffer removed from around roads, paved areas, buildings and the park boundary, to reduce the likelihood of plot disturbance by humans. A 25 meter buffer was used for SAAN due to its small size.

Acronym	Park	Park area in hectares (ha)	Sampling polygons area (ha)	Major habitats represented, in order of dominance	Number of focal units	Total plot allocation per park
GUIS	Gulf Islands National Seashore, Florida and Mississippi	55,846 (total); 4,968 (land)	685	Forest and woodland [upland forest to swamp, dry to wet pine savannah], shrubland, marsh	5	33
JELA*	Jean Lafitte National Historical Park and Preserve, Louisiana	8,100	3,357	Forest [bottomland forest to swamp], marsh, shrubland	2	30
NATR	Natchez Trace Parkway, Mississippi, Alabama and Tennessee	21,160	664	Forest [upland forest to swamp], managed grassland	5	32
VICK*	Vicksburg National Military Park, Mississippi	733	312	Upland deciduous forest	1	10
BITH	Big Thicket National Preserve, Texas	43,385	13,864	Forest and woodland [upland forest to swamp, dry to wet pine savannah]	5	56
PAIS	Padre Island National Seashore, Texas	52,784 (total); 23,516 (land)	788	Grassland and marsh	4	32
PAAL*	Padre Island National Seashore, Texas	696	556	Grassland, shrubland [Tamaulipan thorn-scrub]	1	11
SAAN	San Antonio Missions National Historical Park, Texas	190	55	Forest and woodland [upland to bottomland forest, sugarberry woodland], shrubland, grassland	2	10
Totals	**–**	**102,748 (land only)**	**20,281**	**–**	**25**	**214**

Table 4. The number of plots per focal unit within each park, the unit's area, and the plots per hectare of that unit. The sampling year column indicates the four parks that are sampled in the first year (1) and the four parks that are sampled in the second year (2). A given plot is always sampled in the same month across visits, resulting in the units being revisited in a consistent order. To distribute plots within units, polygons were drawn to encompass the entire unit area, excluding any manicured lawns, waterbodies, paved areas, roads (paved or unpaved) or buildings. Also excluded were 50 meter buffers (or 25 meters for SAAN) around roads, buildings and park boundaries. For the seashore units marked with *, unvegetated or sensitive habitats were also excluded (active dunes, beaches washover zones, and tidal flats). Plots were then randomly distributed within these polygons, with the only requirement of ≥250 meter spacing between plot centers.

Sampling year	Park	Unit name (abbrev)	Number of plots in unit:	Unit being sampled[1]	Area of polygon (ha)	Plots per 100 ha.
1	GUIS	NL	10	Naval Live Oaks Unit, Gulf Breeze, FL: entire unit	252	4.0
1	GUIS	FP*	5	Ft. Pickens Area on west end of Santa Rosa Island, FL: small patches adjacent to beaches and campgrounds	21	23.8
1	GUIS	DB	5	Davis Bayou Unit, Ocean Springs, MS: entire unit except waterbodies including lowest-lying salt marshes	29	17.1
1	GUIS	HI*	8	Horn Island, MS: central third island, which is accessible by a boat landing	314	3.5
1	GUIS	PB*	5	Petit Bois Island, MS: central portion of island	69	7.2
1	JELA	BP-forest	18	Barataria Preserve and adjacent sub-units, Marrero, LA: bottomland forest/swamp portion	1239	1.5
1	JELA	BP-marsh	12	Barataria Preserve and adjacent sub-units, Marrero, LA: lowland marsh portion	2118	0.6
1	NATR	ML	8	Meriwether Lewis Area, TN: entire unit	267	3.0
1	NATR	CF	7	Colbert Ferry Area, north of Tupelo, MS: entire unit	159	4.4
1	NATR	CV	4	Chickasaw Village Area near Tupelo, MS: entire unit	16	24.7
1	NATR	JB	5	Jeff Busby Area south of Tupelo, MS: entire unit	44	11.3
1	NATR	RS	8	Rocky Springs Area north of Port Gibson, MS: entire unit	178	4.5
1	VICK	VI	10	Vicksburg National Military Park, MS: entire park area	312	4.2

[1] always excluding buildings, paved areas, roads, lawns, and waterbodies plus buffers

Table 4 (continued). The number of plots per focal unit within each park, the unit's area, and the plots per hectare of that unit. The sampling year column indicates the four parks that are sampled in the first year (1) and the four parks that are sampled in the second year (2). A given plot is always sampled in the same month across visits, resulting in the units being revisited in a consistent order. To distribute plots within units, polygons were drawn to encompass the entire unit area, excluding any manicured lawns, waterbodies, paved areas, roads (paved or unpaved) or buildings. Also excluded were 50 meter buffers (or 25 meters for SAAN) around roads, buildings and park boundaries. For the seashore units marked with *, unvegetated or sensitive habitats were also excluded (active dunes, beaches washover zones, and tidal flats). Plots were then randomly distributed within these polygons, with the only requirement of ≥250 meter spacing between plot centers.

Sampling year	Park	Unit name (abbrev)	Number of plots in unit:	Unit being sampled[1]	Area of polygon (ha)	Plots per 100 ha.
2	BITH	BC	10	Beech Creek Unit, Woodville, TX: entire unit	1819	0.5
2	BITH	JG	10	Jack Gore Baygall Unit, Kountze, TX: central corridor area	1077	0.9
2	BITH	TC	12	Turkey Creek Unit, Kountze, TX: entire unit	2796	0.4
2	BITH	LR	12	Lance Rosier Unit, Saratoga, TX: northeastern section	3048	0.4
2	BITH	BS	12	Big Sandy Unit, Saratoga, TX: entire unit	5124	0.2
2	PAIS	8*	8	Sampling Unit #8 (most-north), south of Corpus Christi, TX: entire unit	197	4.1
2	PAIS	18*	8	Sampling Unit #18 (mid-north), near Baffin Bay, TX: entire unit	197	4.1
2	PAIS	28*	8	Sampling Unit #28 (mid-south), near Baffin Bay, TX: entire unit	197	4.1
2	PAIS	38*	8	Sampling Unit #38 (most-south), south of Baffin Bay, TX: entire unit	197	4.1
2	PAAL	BA	11	PAAL, Brownsville, TX: entire park area including newly acquired lands	556	2.0
2	SAAN	MI	5	Missions area, San Antonio, TX: small vegetation patches adjacent to missions or along waterbodies	33	15.4
2	SAAN	RA	5	Rancho Unit, Floresville, TX: entire unit	22	22.7

[1] always excluding buildings, paved areas, roads, lawns, and waterbodies plus buffers

Temporal Allocation

Field work for this protocol is conducted in spring, summer and early fall (April–September), during the growing, flowering and/or fruiting season of most plants in each park. All eight network parks are sampled in a three-year monitoring cycle; park sampling occurs in year one and year two, followed by analysis and reporting of all data in year three of each three-year cycle. The year one panel consists of GUIS, JELA, NATR, and VICK, for a total of 105 plots (plus five randomly-selected plots for QA/QC resampling). The year two panel consists of BITH, PAIS, PAAL, and SAAN, for a total of 109 plots (plus five QA/QC plots). Note that BITH, PAIS, and JELA require greater inter-plot field travel distances and time than do other parks. In the event of budgetary shortfalls, sampling frequency shifts to a four-year cycle, with 1/3 of plots completed in each of years one, two and three (GUIS with NATR and VICK; SAAN with BITH; PAIS with PAAL and JELA). For the intended 3-year cycle model, a summary of the spatial and temporal design for each monitoring objective is provided in Table 5.

Table 5. Monitoring objectives, sampling frame, and scale of analyses at GULN parks as a part of the protocol for monitoring terrestrial vegetation.

Objective	Area Sampled	Spatial Design and Plot Area	Temporal Design	Scale of Analysis
Status and trends in species richness	10 to 56 plots in each park, or 4 to 18 in each targeted unit	Simple random distribution of fixed, nested plots within park or target unit. Richness is recorded in each of eight 1 x 1 m quadrats, eight 3.16 x 31.6 m microplots and in four 10 × 10 sub-plots that cover the full 20 × 20 m plot.	Data are recorded for all plots in a park during a single sampling season, conducted once every three years	The plot is the sampling unit for analysis. Richness can be represented as a mean across quadrats, microplots, subplots or even as the simple plot total. Data for each park are summarized after each sampling event, once every three years. When multiple, distinct habitat types are represented within a park, habitats may be summarized separately. Trend analyses require at least three sampling events per plot and may be performed separately for different habitat types within each park (requiring at least 4 plots per habitat type)
Status and trends in percent coverage for vascular plant species	10 to 56 plots in each park, or 4 to 18 in each targeted unit	Simple random distribution of fixed, nested plots within park or target unit. Cover is recorded for all species in each of eight 1 × 1 m (1 m^2) quadrats. Cover is additionally recorded for non-tree species in four 3.16 × 3.16 m (10 m^2) microplots.	Data are recorded for all plots in a park during a single sampling season, conducted once every three years	The 1 m^2 quadrats and 10 m^2 microplots are the sampling units, nested as eight or four per plot. Summaries and analyses typically focus on plant guilds or focal, common species, with the appropriately-sized scale (microplot or quadrat) used for that species. Data for each park are summarized after each sampling event, once every three years. Trend analyses require at least three sampling events per plot and may be performed separately for different habitat types within each park (requiring at least 4 plots per habitat type)

Table 5 (continued). Monitoring objectives, sampling frame, and scale of analyses at GULN parks as a part of the protocol for monitoring terrestrial vegetation.

Objective	Area Sampled	Spatial Design and Plot Area	Temporal Design	Scale of Analysis
Status and trends in relative frequency of vascular plant species	10 to 56 plots in each park, or 4 to 18 in each targeted unit	Simple random distribution of fixed, nested plots within park or target unit. Nested frequency is recorded at three plot sizes, and the optimal size (the smallest size with frequency between 20 and 80%) is selected for each species.	Data are recorded for all plots in a park during a single sampling season, conducted once every three years	The plot is the sampling unit. Summaries and analyses typically focus on plant guilds or focal, common species. Data for each park are summarized after each sampling event, once every three years. Trend analyses require at least three sampling events per plot and may be performed separately for different habitat types within each park (requiring at least 4 plots per habitat type)
Status and trends in canopy closure, basal area, stem density and mortality across species. Within species or focal groups, status and trends in tree growth (DBH), tree mortality, tree condition, and tree regeneration. Qualitative photopoints	10 to 56 plots in each park, or 4 to 18 in each targeted unit	Simple random distribution of fixed, nested plots within park or target unit. Trees are tagged and their metrics are recorded in the 20 × 20 m plot. Seedlings and saplings are counted in the four 10 m^2 plots.	Data are recorded for all tagged individuals and all plots in a park during a single sampling season, conducted once every three years	For metrics that combine different species, the 20 x 20 plot is the sampling unit. For metrics that are species-specific or for focal groups, either the full plot, the 10 m^2 microplot or the tagged individual is the sampling unit. Data for each park are summarized after each sampling event, once every three years. Trend analyses require at least three sampling events per plot and may be performed separately for different habitat types within each park (requiring at least 4 plots per habitat type)

Power Analysis

The Gulf Coast Network adheres to the same standard for statistical power as outlined in the NETN protocol. The Northeast Temperate Network sets their type I error rate at 10% (i.e., probability that change is detected when none exists; often called alpha or significance level), their type II error rate at 20% (i.e., probability that true change is not detected; one minus type II error = statistical power), and their minimum detectable effect size at 40% cumulatively over three sampling intervals. In other words, a key expectation of the design is that sample sizes and sampling frequency are sufficient to allow detection of at least a 40% increase or decrease in a given vegetation metric with 80% power and a false positive rate of 10%.

Although the Gulf Coast Network has no pilot data of their own for a preliminary assessment of power, the Coastal Reference Monitoring System (CRMS) uses a similar sampling design and monitors six 20 × 20 meter (65.6 × 65.6 ft) vegetation plots in JELA (see CRMS 2016a,b for data sources). These plots were sampled in 2012 and 2015, which is the same three-year timescale as GULN vegetation monitoring. To determine if a sample size of four or six plots could meet GULN/NETN targets for trend detection at this site, a power analysis was performed using five vegetation metrics. These metrics were basal area of all live trees, percent cover of all native herbs, percent cover of all invasive herbs, native species richness, and invasive species richness. For all metrics except those involving invasive species, the minimum detectable percent change would meet or surpass the 40% target at ≥ 80% power, using either four or six plots. Section C in the Supplemental Materials packet (Carlson et al. 2018b) provides the descriptions of the dataset, methods, and full results from this preliminary power analysis following the methods of Miller and Mitchell (2014).

Section 6. Data Management, Analysis, and Reporting

Data Management and Process Workflows

The Gulf Coast Network has adopted the data processing steps and QA/QC procedures of the NETN Forest Monitoring Protocol. As necessary, the Gulf Coast Network has modified NETN procedures and workflow specifications to maintain consistency with current I&M standards and with the GULN's approved data management plan for the network and its implementation (Granger 2007). A full description of this protocol's data management plan and QA/QC practices is provided in GULN SOP VEG09 *Data Management and Quality Assurance/Quality Control* (Carlson et al. 2018c). To summarize, the data management workflow is as follows (see also Table 6):

1. **Preparation**—the field crew is trained, trip logistics are planned, supplies are assembled following equipment lists, and paper datasheets are printed (three different sheets per site with spare copies of each).

2. **Data acquisition**—Data are collected by the field crew onto three paper datasheets per site, in accordance with all SOP instructions. The final products from this step are raw datasheets.

3. **Datasheet review/verification**—Prior to departing the field site, the data recorder reviews the datasheet for completeness and then initials the front. Datasheets are digitally scanned or photographed at the end of the field day to create a backup copy. The final products from this step are verified paper datasheets.

4. **Datasheet validation**—The ecologist or field lead (botanical background required) checks each datasheet for realistic entries, the use of correct and current taxonomy for species IDs, and the correct spelling of Latin names. The final products from this step are validated paper datasheets.

5. **Accepted datasheets**—After the paper datasheets are validated, they are digitally scanned and stored as the final, accepted datasheet.

6. **Data entry, processing, and backup**—All entries that were recorded on the paper datasheets are entered into the vegetation monitoring database as soon as possible after data collection. This is completed on computers in the GULN office or, less frequently, on a field computer while on travel. The Gulf Coast Network uses a modified version of the NETN database, which was developed by the NETN data manager. At the end of each field day, photos are downloaded onto the travel laptop, renamed, and organized in folders. The photos and datasheet scans should be backed up on an external drive on a daily basis. If any data are entered into the database while the field crew is on travel, the database should be backed up at the end of the day. The final product of this step is a raw, entered data set.

7. **Database verification and quality review**—As data are entered from paper datasheets into the database, multiple verification checks are performed. First, after entering each datasheet into the database, the typist compares the database and datasheet to ensure all typed numbers

match what was written. Second, a different crew member reviews all datasheets entered that day to again ensure that all typed data match the datasheet. This is the 100% check. Third, either the data manager or protocol lead reviews 10% of all datasheets, again for proper entry from the datasheet. 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.

8. **Database validation**—After data are verified as entered correctly, additional validation tests are completed by the ecologist to ensure that data in the database is logically consistent and realistic. These steps include plotting data points, calculating summary statistics, and reviewing species lists. At the end of this stage, the products are validated data in the database.

9. **Accepted database**—After verification and validation steps are complete, the data are classified as accepted. If there is an applicable Quality Assurance Plan (QAP) that covers the data, they can then be considered certified.

10. **Metadata/documentation and data delivery**—All data that are accepted or certified are accompanied by metadata that describe the 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 the final sampling event for a given field season.

11. **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. Vegetation Monitoring Event and Status Reports are created during the third (non-sampling) year of each three-year cycle. After the first three surveys per site are completed and summarized, more in-depth reports on 'Status and Trends in Vegetation' are prepared, including results of statistical analyses of cross-year trends.

12. **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 datasheets, are posted to the NPS Integrated Resource Management Applications (IRMA) Data Store on an annual basis.

QA/QC

As in the NETN protocol, the Gulf Coast Network resamples approximately 5% of sampled plots annually to determine reliability of data collection. These methods for quality control and quality assurance are specified within GULN SOP VEG09 *Data Management & Quality Assurance/Quality Control* (Carlson et al. 2018c).

Data Processing and Data Quality Levels

The data processing steps, their associated products, and their frequency of completion are listed in Table 6. Table 6 also introduces the three stages of data processing: raw, provisional, and accepted.

Raw data are in their original form, either as a field datasheet, photo, or a raw entry into the database. Provisional data have undergone verification steps but are not suitable for general use. Accepted data (or certified data, if the QAP for the protocol is in place) are products from the provisional data step that have been validated 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 accompanies all archived annual data products on the GULN server and is distributed with data requests and uploads to national databases. See GULN SOP—*VEG09* for additional details.

Table 6. Data processing steps and products for the GULN Terrestrial Vegetation Monitoring protocol.

Data type	Data stage (going in)	Processing step	Product name (going out)	Expected frequency of completion
Data-sheets	NA	1. Datasheets are filled-in by hand in the field.	Raw datasheets	At the end of each plot sampling event
	Raw	2. Datasheets are reviewed for completeness and initialed at the end of fieldwork.	Reviewed/verified datasheets	At the end of each plot sampling event
	Provisional	3. Datasheets are reviewed by the ecologist or protocol lead for spelling, current taxonomy, and realistic values.	Validated datasheets	At the end of each field sampling day or within a week
	Accepted	4. Datasheets are digitally scanned.	Scanned, validated, and accepted datasheets	At the end of each field sampling day or within a week
	Accepted	5. Paper datasheets are managed as long-term records.	Local storage of accepted datasheets	Within three months of field season's end
	Accepted	6. Scanned field forms are published to NPS Data Store or IRMA.	Offsite archive and publication of accepted datasheet	Within one year of field season's end
Photos/ image data	NA	1. Digital 'photopoint' photos are taken.	Raw photos	At the end of each plot sampling event
	Raw	2. All photos are downloaded and renamed.	Renamed and organized digital photos	At the end of each field sampling day
	Provisional	3. Each photo is viewed on-screen to ensure proper camera orientation.	Reviewed digital images	At the end of each field sampling day
	Accepted	4. Photos are archived locally.	Local archive of photos	Within five months of field season's end

Table 6. (continued) Data processing steps and products for the GULN Terrestrial Vegetation Monitoring protocol.

Data type	Data stage (going in)	Processing step	Product name (going out)	Expected frequency of completion
Photos/ image data (cont.)	Accepted	5. Photopoint photos are used qualitative verify changes that are apparent in analyses and to illustrate trends for reports.	'Vegetation Monitoring Event and Status Reports' and 'Status and Trends in Park Vegetation' reports	Event Reports: by end of third (non-sampling) year of each 3-year cycle. Status and Trends: after 3 data collection events for a park
Vegetation monitoring database	NA	1. Accepted datasheets 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 crew 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 datasheets for a given field season for accurate transcription.	Verified data	Within one month of field season's end
	Provisional	5. Ecologist creates summary statistics and plots data to identify and flag outliers	Partially validated data	Within three months of field season's end
	Provisional	6. Ecologist reviews species lists and checks IDs for unexpected records.	Validated data	Within three months of field season's end
	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 field season's end
	Accepted	8. Database backends of accepted data are published to NPS IRMA Data Store.	Offsite archive and publication	Within one year of field season's end

Table 6. (continued) Data processing steps and products for the GULN Terrestrial Vegetation Monitoring protocol.

Data type	Data stage (going in)	Processing step	Product name (going out)	Expected frequency of completion
Vegetation monitoring database (cont.)	Accepted	9. Data are analyzed, and reports are written based on the results.	'Vegetation Monitoring Event and Status Reports' and 'Status and Trends in Vegetation' reports	Event Reports: by end of third (non-sampling) year of each three-year cycle. Status and Trends: after three data collection events for a park

Data Archiving

Instructions for archiving and posting data are included in GULN SOP VEG09. To summarize, after digital products are processed and approved (for reports) or accepted/certified (for data sets), the data manager archives them and prepares for posting them to Integrated Resources Management Applications (IRMA). IRMA is the NPS clearinghouse for natural resource data and metadata. The types of products that are posted on IRMA for this project include Vegetation Monitoring Event and Status Reports (after all parks have had one field season), Status and Trends in Vegetation reports (after three rounds of data collection per park, although can be more frequent after the first report), digital scans of data sheets, and Microsoft Excel exports of annual data sets from the NPS GULN Vegetation 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 Terrestrial Vegetation Monitoring Project that houses all products uploaded to IRMA. Refer to the IRMA website for upload and product linking instructions.

When a product is posted on IRMA, the data manager creates a reference record for it that is specific to the IRMA platform (refer to the IRMA website for reference creation and upload instructions). The reference record contains citation information, relevant metadata and keywords. This is done for all products, including reports, other publications, data sets, 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 function of IRMA.

Procedure for Revising the Protocol

Over time, revisions to both the protocol implementation plan and SOPs are expected. Careful documentation of changes to the plan and a library of previous 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 VEG11 *Protocol and Database Revisions* (Carlson and Segura 2018f). The protocol implementation plan and each SOP contain a revision log to fill out each time the main document or a 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 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

The Gulf Coast Network follows two time intervals for assessing and reporting on the status and trends in specific vegetation measures within each park. The first reporting interval is after a single sampling season is completed in each park, which is the third (non-sampling) year of each three-year cycle. At this time, the GULN ecologist produces for each park a Vegetation Monitoring Event and Status Report, which includes text, figures and tables for the most recent sampling event on the park. Focal variables provided for each plot include species richness; percent coverage of plant guilds (shrub, liana/vine, graminoid and herbaceous plants) or focal species; relative frequency of plant guilds or focal species; canopy closure, basal area, and stem density across tree species; growth, DBH, mortality, and regeneration per tree species or group of tree species. If multiple, distinct habitat types are represented within a park, separate data summaries are provided for plots in each habitat type. The eight Event and Status Reports are produced over the 12 months after all parks have been sampled once. Writing begins three months after data collection is complete, once all relevant data have passed the verification and validation steps to be accepted or certified data.

The second reporting interval is after each plot has been sampled three times. At this interval, the Gulf Coast Network completes one “Status and Trends in Vegetation” report for each park. These reports include longer-term summaries of findings, spanning either the three most recent sampling events, or where appropriate, to the start of the sampling effort. Crucially, these reports present visualization and analysis of cross-year trends in focal vegetation metrics, going back to the start of the monitoring effort. If multiple, distinct habitat types are represented for a single park, trend analyses may be performed separately for each habitat type and be limited to only those habitat types with at least four plots representing them. A preliminary assessment of vegetation communities in GULN plots indicates all parks have at least four plots per broad physiographic class, with woodlands and forests combined. For more information on sample sizes by habitat type, see Table B-1 in the Supplemental Materials packet (Carlson et al. 2018b). Analysis and writing of the Status and Trends reports can begin after all relevant data sets have become accepted or certified, which occurs within three months after the final round of data collection for that report.

All or most of the focal variables reported on in the Event and Status reports are also used in trend analyses. Exceptions include those that are redundant with another variable or prone to low power-of-detection. Trends are analyzed using generalized linear or linear mixed models that account for repeated measures on plots within parks. One suitable statistical package for these models is lme4 in R (Bates et al. 2015; R Core Team 2014). Generalized models are used to allow for non-Gaussian distributions, such as negative binomial or Poisson (for count data) or binomial (for proportions). Random effects, covariates (such as weather or disturbance metrics) and repeated measures on plots are included to reduce unexplained variability for detecting trends. Full descriptions of the steps in data analysis and reporting are in GULN SOP VEG10 *Data analysis and reporting* (Carlson 2018). It should be noted that many of the focal variables and analyses have parallels to the NETN Protocol, but a primary difference is that the Gulf Coast Network does not report on ecological integrity. After the first Status and Trends report, the network provides new updates on trends no less frequently than once per three sampling events, with the option of reporting after just one or two new events, to meet park-specific needs and interests.

In addition to these two prescribed reporting formats, the network is also able to report to parks, stakeholders and the public on an unscheduled basis. One type of unscheduled report is the resource brief, which consists of a one to two page summary that provides the park with a quick and readily accessible overview of a GULN project. These summaries report on resource status, monitoring progress, salient observed events, and related matters of general interest. Resource briefs are produced and updated on an unscheduled basis, with the intent to provide readers a timely first look at the subject. Another type of unscheduled report comes in the form of peer-reviewed publications and presentations. Publishing monitoring results in scientific journals or giving presentations at scientific meetings allows the network to reach the scientific community in a way that internal NPS reports cannot. Peer-reviewed publications may serve the purpose of promoting investigation by members of the scientific community, either independently or in cooperation with the network. Ultimately, publication in peer-reviewed publications and the collaboration that ensues should foster a greater understanding of ecosystem components and processes.

Section 7. Budget

The estimated annual cost (based on FY2016 dollars) of implementation of the GULN Terrestrial Vegetation Protocol is presented in Table 7. The budget is based on estimated per-plot sampling costs plus apportioned data-management support costs developed using a hypothetical GULN staff team for all work. The Gulf Coast Network may have sampling performed by non-NPS personnel. In these cases, they use the staff-based per-plot cost as a guideline for developing those contracts and agreements. Parks may provide support for monitoring, including staff participation in sampling, logistical support, and site access assistance, including transport by boat (GUIS), airboat (JELA), and UTV and/or other vehicles (BITH, PAAL, PAIS), and housing support for team personnel when available (BITH, GUIS, PAIS). This budget does not include support provided by parks or other partners and should be considered a maximum cost estimate assuming full travel and personnel costs needed to implement the protocol.

The GULN ecologist provides project oversight. Field work is performed by a team of three consisting of the network ecologist or one GS-11 or equivalent seasonal-hire botanist as team lead, plus one GS-07 or equivalent bio-technician, and one GS-05 or equivalent bio-technician. Data management is supervised by the GULN data manager.

Field work occurs in two of each three years per implementation cycle. Year three is used for data analysis and reporting. A total of 224 plots (including 10 QA/QC resamples) are sampled across all eight network parks (105 plots plus 5 resamples in year one, and 109 plus 5 resamples in year two). The Gulf Coast Network estimates that 1.6 plots can be completed per day, averaged over all eight parks. For some parks, it is unlikely that multiple plots can be completed most days (e.g., BITH, NATR), but in other parks, two or even three per day is possible (e.g., PAAL, PAIS, marsh in JELA). Several I&M vegetation monitoring protocols estimate that two plots can be completed per day (e.g., CACO, CUPN). The Northeast Temperate Network estimates that one plot can be completed in 2.5–3.5 hours, plus travel time (Tierney et al. 2016). Great Lakes Network estimates that one plot can be completed per day.

The following budget is for the second of the two sampling years, which requires more effort than the first year. This year has 71 field-days at 1.6 plots per day plus two field training days for the botanist and bio-technician, and 15 data-manager days. In general, we assume that data management is approximately 30% of the project cost. Consequently, the estimated field days are increased by 30% to account for data management, data entry, and data QA/QC. Daily personnel costs are based on the Office of Personnel Management (OPM) salary table for the rest of the U.S. with an estimate of 40% fringe benefit cost. Because of the distances between parks and between the network office and the parks, we also assume that each park requires an additional two days of travel where no sampling occurs. The estimated travel budget assumes that no park housing is available and uses the standard per diem rate ($91 lodging, $51 M&IE). The actual cost is likely to be less when park housing is available (BITH, PAIS, and GUIS) or if field crews are based closer to parks. The categories of expenditures, required efforts and their associated costs are detailed in Table 7.

Table 7. Estimated annual operating cost (based on FY2016 dollars) for implementation of the GULN Terrestrial Vegetation.

Category	Type	No. of Days	Cost per Day	Total Cost	Notes
Personnel	GULN Network Ecologist (GS12/2)	50	$394	$19,690	36 field days, 4 travel days, 10 days data management
	GULN Data Manager (GS11/8)	15	$392	$5,882	All time spent on data management
	Biological technician (GS7/1 or equivalent)	101	$215	$21,696	73 field days, 8 travel days, 20 days data management
	Biological technician (GS5/1 or equivalent)	81	$173	$14,053	73 field days, 8 travel days
	Botanist (GS11/1 or equivalent)	40	$318	$12,719	Estimate participation in half of the plots, or on contract to aid in species identification.
	Total Personnel Costs	**–**	**–**	**$74,039**	**–**
Equipment and Supplies	Vehicle fuel costs	81	$40	$3,240	Assuming that GULN supplies a network vehicle for a network staff sampling crew.
	Field Supplies	73	$20	$1,095	Insect repellent, plastic bags, hand cleaners, sun block, batteries, spray paint, replacement measuring tapes. replacement plot markers, new tree tags
	Set-up costs for field-equipment and plot establishment	–	–	$6,500	Rebar and fiberglass posts for marking plots, tree tags, plot label markers, field packs, plant presses, measuring and DBH tapes, taxonomic books and references
	Total Equipment Costs	**–**	**–**	**$10,835 first year $ 4,335 other years**	**–**
Travel	Crew Lead	81	$142	$11,502	73 field days, 2 travel days for each of 4 parks sampled each year
	2 Technicians	162	$142	$23,004	73 field day each, 16 travel days
	Total Travel Costs	**–**	**–**	**$34,506**	**–**
Totals	**TOTAL ANNUAL COST**	**–**	**–**	**$119,380 first year $112,880 other yrs.**	**Estimated total implementation cost for each field-year**

Section 8. Safety

Implementation of this protocol has multiple complex risks. Both prior to and during field sampling, staff members evaluate risks at the programmatic, personnel, and site level. Programmatic-level safety information is presented here and is also detailed in the GULN SOP VEG01 *Safety* (Carlson and Segura 2018g). Also in the SOP are procedures to mitigate risks associated with specific activities, such as vehicle use and operation, injury reporting and accident reporting. A separate SOP is included to mitigate risks of moving exotic species in and out of parks during sampling, titled GULN SOP VEG08 *Limiting Exotic Species Transport* (Carlson and Segural 2018h).

Job Hazard Analyses (JHAs) were completed for all personnel involved in GULN vegetation monitoring. These individual JHAs identified risks, risk abatement strategies, and training needs associated with each position. By combining individual JHAs, a JHA for vegetation monitoring field work was produced, which was then used for a programmatic-level Green-Amber-Red (GAR) risk analysis. The field work JHA is included as Appendix B in the safety SOP (Carlson et al. 2018g).

Specific safety concerns include:

- Crew members spend many hours (and miles) driving to, between, and from sampling locations to conduct the requisite sampling.
- Crew members may be working in park areas outside of communications range (either by park radio or by cell phone).
- Crew members are frequently exposed to extreme heat and humidity and are working for extended periods of time in remote areas with potentially rapidly-changing and severe weather conditions.
- Crew members are frequently exposed to thorny or rash-causing plants, stinging and biting insects, treacherous terrain, venomous and other hazardous animals, and potentially hazardous materials and debris left from pre-park land usage, such as old drilling and range equipment, fencing and piping, contaminated soils, and waste materials.
- In specific cases, crew members travel by watercraft and UTV / ATV for site-access and are exposed to increased risks associated with use of this equipment.

Injury or loss of life while in transit to and from field sites and during sampling activities within sites—as well as while in transit to or from sampling sites via watercraft and UTV / ATV—are the most significant risks encountered when conducting this activity.

Based on the JHA and associated risk abatement measures, it was determined that this protocol can be safely implemented. This is provided that GULN and partner staff members follow all referenced SOPs and recommended risk abatement strategies. In addition to SOPs, specific training needs for all staff have been identified, and they include certification in basic first aid. To increase the overall level of safety and awareness, obtaining additional levels of training beyond basic certifications is encouraged.

Safety procedures are routinely reviewed with network staff and partners before field operations, as prescribed in SOPs. Personnel-level JHAs for staff are reviewed and revised annually as a part of the performance review cycle. Safety SOPs are reviewed at least annually and updated as necessary to ensure that they adequately mitigate risks to personnel, property, and the public. In addition to protocol-specific safety procedures and guidelines, GULN staff members follow the general guidelines set forth in the NPS Occupational Safety and Health Program Reference Manual (Directors Order #50B; NPS 2008).

Section 9. Standard Operating Procedures and Deviations from Source Protocols

To ensure consistent implementation of this protocol over time, the following Standard Operating Procedures (SOPs) have been adopted from NETN SOPs or developed as needed by GULN (Table 8). All approved versions of operational SOPs are available for download in the GULN Terrestrial Vegetation Monitoring Project on IRMA.

Table 8. Standard Operating Procedures required to implement the NETN Terrestrial Vegetation Monitoring Protocol in GULN parks. The table includes a brief description of changes from the source document to the GULN version. Additional details on these changes are provided at the start of each GULN SOP. A full citation for the source protocol is provided in the literature cited section.

Topic	Source Protocol	Explanation of Differences	GULN Updated SOP	Link to Published Document / IRMA Record
Safety: (Emergency contacts and preparedness, Job Hazards, Injuries, Vehicle Use)	NETN SOP—1 Safety (Tierney et al. 2016)	Changes were made to the SOP to align with GULN's structural organization, differing field work hazards, and GULN's use of only one field crew per season. All appendices except the Job hazard/safety assessment were removed from this SOP and placed in a field safety packet. Minor adjustments were made to the NETN protocol regarding format and length.	SOP VEG01 Safety (Carlson and Segura 2018g)	2255905
Monitoring: Preparation for field-work	NETN SOP—2 Preparation and Equipment List (Tierney et al. 2016)	Very minor editorial changes and changes to equipment lists.	SOP VEG02 Preparation and Equipment List (Carlson and Segura 2018b)	2255905
Monitoring: Field-work	NETN SOP—6 Site Selection, Plot Establishment and Remeasurement (Tierney et al. 2016)	The plot design and physiographic classes were modified to better suit GULN parks. The approach to plot selection is also different from NETN, due to limited network resources and the stated preferences of GULN park managers and staff.	SOP VEG03 Site Selection, Plot Establishment and Return Visits (Carlson et al. 2018a)	2255905

Table 8 (continued). Standard Operating Procedures required to implement the NETN Terrestrial Vegetation Monitoring Protocol in GULN parks. The table includes a brief description of changes from the source document to the GULN version. Additional details on these changes are provided at the start of each GULN SOP. A full citation for the source protocol is provided in the literature cited section.

Topic	Source Protocol	Explanation of Differences	GULN Updated SOP	Link to Published Document / IRMA Record
Monitoring: Field-work	NETN SOP—8 Stand and Site Measurements (Tierney et al. 2016)	Several forestry-related metrics were eliminated to better accommodate both forested and non-forested plant communities of GULN parks. These include stand structure, stand height and crown closure. Deer browse index was also removed. The SOP's organization was modified to accommodate the associated GULN datasheet VEG. FORM 1 (Appendix D; Carlson et al. 2018)	SOP VEG04 Site Measurements (Carlson and Segura 2018c)	2255905
Monitoring: Field-work	NETN SOP—9 Tree Measurements (Tierney et al. 2016)	Reduced the amount and types of information collected on tree condition and foliage condition. Some definitions were changed to better encompass the diverse tree types and growth forms in GULN parks. The SOP's organization was modified to accommodate the associated GULN datasheet VEG. FORM 2 (Appendix D; Carlson et al. 2018).	SOP VEG05 Tree Measurements (Carlson and Segura 2018e)	2255905
Monitoring: Field-work	Combination of two NETN SOPs: SOP—10 Microplot and SOP—13 Quadrat Measurements (Tierney et al. 2016)	Nested frequency measurements were added to the SOP, which require some additional data collection within three sampling unit sizes (see USEPA 2016). The approach for percent cover was changed to add estimation of percent cover for all non-tree plant species in four 3.16 x 3.16 meter microplots, rather than just percent cover of shrubs at that scale. Some definitions were changed to better encompass the diverse tree types and growth forms in GULN parks. The SOP's organization was modified to accommodate the associated GULN datasheet VEG. FORM 3 (Appendix D; Carlson et al. 2018b).	SOP VEG06 Vascular Plant Species Presence, Cover and Abundance (Carlson and Segura 2018a)	2255905

Table 8 (continued). Standard Operating Procedures required to implement the NETN Terrestrial Vegetation Monitoring Protocol in GULN parks. The table includes a brief description of changes from the source document to the GULN version. Additional details on these changes are provided at the start of each GULN SOP. A full citation for the source protocol is provided in the literature cited section.

Topic	Source Protocol	Explanation of Differences	GULN Updated SOP	Link to Published Document / IRMA Record
Monitoring: Fieldwork photography	NETN SOP—7 Photopoint (Tierney et al. 2016)	Very minor editorial changes and one change to a photo location and naming convention due to a different plot layout.	SOP VEG07 Photopoint (Carlson and Segura 2018d)	2255905
Monitoring: Post-sampling	NETN SOP—15 Limiting Exotic Species Transport (LEST) (Tierney et al. 2016)	Very minor editorial changes to better reflect GULN parks.	SOP VEG08 Limiting Exotic Species Transport (Carlson and Segura 2018h)	2255905
Data Management	NETN SOP—5 Data Management and QA/QC (Tierney et al. 2016)	The NETN SOP was modified extensively to describe the entire data management workflow according to current GULN standards (Granger 2007) and recent data management guidance. Also, data are not entered in the field onto field laptops. Relevant definitions were added to clarify steps in the workflow process.	SOP VEG09 Data Management and QA/QC (Carlson et al. 2018c)	2255905
Data Analysis and Reporting	New SOP written by Gulf Coast Network staff for this protocol	Protocol developed by GULN to reflect their general approach to analysis and reporting practices. NETN uses an ecological scorecard approach for its reporting, and the GULN does not.	SOP VEG10 Data Analysis and Reporting (Carlson 2018)	2255905
Revising Protocols and Procedures	NETN SOP—19 Protocol and Database Revision (Tierney et al. 2016)	Minor editorial changes and some additions to use consistent language and structure, relative to other GULN Protocol Revisions SOPs	SOP VEG11 Protocol and Database Revision (Carlson and Segura 2018f)	2255905

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List of In-House Documents Required by the GULN Protocol Implementation Plan and SOPs

1. Field Safety Packet and Pamphlet. Required by SOP—*VEG01 Safety*.

2. In-House Document: Welcome Packet for GULN Field Crew Members, to be mailed or emailed prior to the start of the field season. Required by *SOP—VEG02 Preparation and Equipment List*.

3. In-House Documents: Training Materials and Powerpoints for GULN Terrestrial Vegetation Monitoring Protocol. Required by SOP—*VEG02 Preparation and Equipment List*.

4. In-House Document: Operating the GPS and Rangefinder in the Field. Required by SOP—*VEG03 Site Selection, Plot Establishment and Return Visits*.

5. In-House Document: Differential Correction by Postprocessing. Required by SOP—*VEG03 Site Selection, Plot Establishment and Return Visits*.

6. In-House Document: Data Entry. Required by SOP—*VEG09 Data Management & QA/QC*.

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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