



South Florida/Caribbean Network Forest Vegetation Monitoring

Protocol Implementation Plan

Natural Resource Report NPS/SFCN/NRR—2020/2064



ON THE COVER

Upper left clockwise: Mangrove Forest, Everglades National Park; Pineland Forest, Big Cypress National Preserve; Tropical Dry Forest, Salt River Bay National Historical Park and Ecological Preserve; Upland Moist Forest, Virgin Islands National Park. Photography by: South Florida/Caribbean Network

South Florida/Caribbean Network Forest Vegetation Monitoring

Protocol Implementation Plan

Natural Resource Report NPS/SFCN/NRR—2020/2064

Kevin R. T. Whelan¹, Robert B. Shamblin¹, Michelle Prats¹, Judd M. Patterson¹, Mario Londoño¹,
and Robert Muxo¹

¹National Park Service
South Florida/Caribbean Inventory & Monitoring Network
18001 Old Cutler Rd, Suite 419
Palmetto Bay, FL 33157

January 2020

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

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

The Natural Resource Report Series is used to disseminate comprehensive information and analysis about natural resources and related topics concerning lands managed by the National Park Service. The series supports the advancement of science, informed decision-making, and the achievement of the National Park Service mission. The series also provides a forum for presenting more lengthy results that may not be accepted by publications with page limitations.

All manuscripts in the series receive the appropriate level of peer review to ensure that the information is scientifically credible, technically accurate, appropriately written for the intended audience, and designed and published in a professional manner.

This report received 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.

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

This report is available in digital format from the [South Florida/Caribbean Network](#) and the [Natural Resource Publications Management website](#). If you have difficulty accessing information in this publication, particularly if using assistive technology, please email irma@nps.gov.

Please cite this publication as:

Whelan, K. R. T., R. B. Shamblin, M. Prats, J. M. Patterson, M. Londoño, and R. Muxo. 2020. South Florida/Caribbean Network forest vegetation monitoring: Protocol implementation plan. Natural Resource Report NPS/SFCN/NRR—2020/2064. National Park Service, Fort Collins, Colorado.

Contents

	Page
Figures.....	v
Tables.....	vii
Appendices.....	ix
Executive Summary	xi
Section 1. Introduction.....	1
Background.....	1
Forest Communities in South Florida/Caribbean Network Parks	1
Source Protocol and How It Was Modified.....	5
Section 2. Conceptual Framework for Monitoring	7
Threats to SFCN Park Forest Resources	9
Section 3. Measurable Objectives.....	13
Section 4. What’s Being Measured and How	15
Overview of Methods.....	18
Preparation and Plot Set-Up	18
Field Sampling Methods.....	20
Data Entry and Management	21
Additional Operational Notes.....	21
Section 5. Sampling Design and Monitoring Schedule	23
Sample Size Determination and Power Analysis	24
Spatial Allocation	26
Temporal Allocation.....	27
Section 6. Data Management, Analysis, and Reporting	33
Data Management and Process Workflows.....	33
Step 1—Preparation.....	33
Step 2—Maps and GPS	33
Step 3—Data Acquisition.....	33

Contents (continued)

	Page
Step 4—Datasheet Review and Validation	33
Step 5—Plot Photographs and Plant Photo Vouchers.....	33
Step 6—Accepted Datasheets.....	33
Step 7—Data Entry, Processing, and Backup	34
Step 8—Database Verification and Quality Review	34
Step 9—Database Validation	34
Step 10—Accepted Database	34
Step 11—Protected Data Agreement.....	34
Step 12—Metadata Documentation and Data Delivery	34
Step 13—Data Analysis and Product Development.....	34
Step 14—Product Posting and Distribution	35
Step 15—Protocol Operational Review	35
QA/QC.....	35
Data Processing and Data Quality Levels	35
Data Archiving	37
Procedure for Revising the Protocol.....	38
Data Analysis.....	38
Reporting.....	39
Section 7. Budget	41
Section 8. Safety	45
Section 9. Standard Operating Procedures and Deviations from Source Protocols.....	47
Literature Cited	53

Figures

	Page
Figure 1. South Florida/Caribbean Network park locations.	3
Figure 2. Plant community examples from South Florida/Caribbean Network parks.	5
Figure 3. The standard South Florida/Caribbean Network forest sampling unit, which includes a 20 × 20- meter modified Carolina Vegetation Survey plot and three 25- meter fuel transects.	19

Tables

	Page
Table 1. Parks located within the South Florida/Caribbean Network.	4
Table 2. Vegetation mapping reports and status for South Florida/Caribbean Network parks.	8
Table 3. Identified stressors affecting focal forest resources within South Florida/Caribbean Network parks and potential measures for vital signs monitoring.....	10
Table 4. Monitoring elements, sampling methods, and data collected for the SFCN Forest Vegetation Monitoring Protocol.	16
Table 5. Timeline of forest plot monitoring activities in the South Florida/Caribbean Network from fall 2019 (beginning of Panel 1) to spring 2024 (end of Panel 5).	24
Table 6. Plot allocation within Focal Forest Community types of parks within the NPS South Florida/Caribbean Network.	25
Table 7. Monitoring elements, temporal design, and scale of analysis at South Florida/Caribbean Network parks as part of the protocol for forest vegetation monitoring.....	29
Table 8. Timeline of forest plot monitoring and reporting activities in the South Florida/Caribbean Network from 2019-2034.	31
Table 9. Data processing steps for the SFCN Forest Vegetation Monitoring Protocol.	36
Table 10. Estimated annual operating cost (based on FY2019 dollars) for implementation of the South Florida/Caribbean Network’s Forest Vegetation Monitoring Protocol.....	43
Table 11. Standard Operating Procedures required to implement the SFCN Forest Vegetation Monitoring Protocol in SFCN parks.....	47
Table B-1. Safety SOPs and JHAs.	69

Appendices

	Page
Appendix A: Modifications to the Cumberland Piedmont Network Protocol and Justification for Changes.....	61
Appendix B: Field Safety.....	69

Executive Summary

The South Florida/Caribbean Network (SFCN) conducts long-term forest monitoring as part of the nationwide Inventory and Monitoring Division of the National Park Service. Forest vegetation in parks is monitored as a key vital sign and indicator of overall ecosystem health because changes in forest condition reflect effects of stressors such as extreme weather, disease, invasive species, fire, and land use change. Forest vegetation also provides the structured habitat and food resources on which other species depend. The SFCN forest monitoring protocol concentrates on focal forest communities (typically the dominant forest types) within the SFCN parks and a few additional forest communities of special management concern. These focal forest communities are affected by a combination of physical features and processes that have historically been present (hydrology, salinity, fire, frost, topography, aspect, soil type and depth). Monitoring focal forests over time allows for greater understanding of these ecosystems within the SFCN geography, which provides managers information about the degree of change within these communities.

Forest monitoring takes place in seven national park units within the South Florida/Caribbean Network. Parks include Big Cypress National Preserve (BICY), Biscayne National Park (BISC), Dry Tortugas National Park (DRTO), and Everglades National Park (EVER) in south Florida. In the U.S. Virgin Islands, the SFCN park units are Buck Island Reef National Monument (BUIS), Salt River Bay National Historical Park and Ecological Preserve (SARI), and Virgin Islands National Park (VIIS). The South Florida/Caribbean Network monitors between eight and fifty-four randomly located plots within each park (except for BUIS and DRTO that have one and two plots, respectively). The number of plots depends on several factors, including the total terrestrial area and coverage of focal forest within the park. Monitored focal forests in the South Florida parks include Hardwood Hammocks, Coastal Hardwood Hammocks, Mangrove Forests, Pinelands, and Cypress Forests. In the U.S. Virgin Islands, the focal forests include Mangrove Forests, Tropical Dry Forests, and Tropical Moist Forests. Monitored forest communities of special management concern are Manchineel Forest at BUIS, Black Mangrove Forest at DRTO, and Mangrove Forest in SARI and VIIS. Plots are 20 × 20 meters (65.6 × 65.6 feet [ft]) in size. Data collected in each plot include species richness, species-specific cover and constancy, species-specific woody stem seedling/sapling counts, tree (greater than 5 centimeters [1.97 inches (in)]) diameter at breast height (DBH), site conditions and environmental covariates.

The South Florida/Caribbean Network's approach, rationale, and required resources for forest monitoring are described in this document, the protocol implementation plan narrative. Sixteen 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 some SOPs are derived, in large part, from the *Vegetation Monitoring Protocol for the Cumberland Piedmont Network, Version 1* (White et al. 2011). Additional methods were also adopted from the *Terrestrial Vegetation Monitoring in Southeast Coast Network parks: Protocol Implementation Plan*. (Boyle et al. 2019) and the *Monitoring Vegetation in Gulf Coast Network Parks: Protocol Implementation Plan* (Carlson et al. 2018). These methods and any differences in approach between the various

networks are documented throughout this South Florida/Caribbean Network narrative and the associated SOPs.

Section 1. Introduction

Background

During the initial network scoping process, the *Forest Ecotones and Community Structure* monitoring vital sign was ranked as 14th in importance of the 44 potential vital signs considered by South Florida/Caribbean Network (SFCN) park managers (Patterson et al. 2008).

Forest monitoring is used extensively by the National Park Service (NPS) as a tool that, when used in conjunction with appropriate management, helps preserve National Park resources “unimpaired for future generations” (National Park Service Organic Act of 1916). Within the National Park Service, there are 32 networks engaged in monitoring activities as part of the national Inventory and Monitoring Division (IMD). The South Florida/Caribbean Network is in the NPS Southeast Region, and serves seven national park units with significant cultural and natural resources. Like the other networks, the South Florida/Caribbean 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). Forest ecotones and community structure monitoring was identified as one of the seventeen vital signs within the South Florida/Caribbean Network (Patterson et al. 2008). The forest ecotone component was removed from this protocol and is addressed in the South Florida/Caribbean Network mangrove-marsh ecotone monitoring protocol (Moser et al. 2019). This protocol implementation plan outlines how the South Florida/Caribbean Network collects, manages, and reports monitoring data for its Forest Vegetation Monitoring Vital Sign, thus addressing a range of terrestrial attributes across all network parks.

Forest Communities in South Florida/Caribbean Network Parks

The South Florida/Caribbean Network includes a total of seven parks in South Florida and the Caribbean (Figure 1, Table 1). The forest vegetation within the parks is influenced by factors such as latitude, longitude, elevation, geology, topographic position, hydrology, nutrients, land use, fire history, distance from the shore, and climate change. South Florida/Caribbean Network parks are highly diverse, with just under 1,985 known vascular plant species across the network (excludes Salt River Bay National Historical Park and Ecological Preserve [SARI], which is not listed in NPSpecies [NPS 2016]). South Florida parks, such as Big Cypress National Preserve and Biscayne National Park, have approximately 1,051 and 462 species, respectively. The Caribbean parks, such as Virgin Island National Park and Buck Island Reef National Monument, host over 712 and 234 species, respectively. Vegetation communities vary widely across the network parks (NPS 2016). In SFCN park units, there are approximately 300 vegetation associations in which there is a defined dominant overstory and associated understory plants (i.e., that are equivalent to the fine-resolution floristic description of alliance-association as described by the *National Vegetation and Classification Standard, Version 2.0* [Federal Geographic Data Committee 2008]). A high degree of uniqueness and diversity in the forest vegetation communities is found in these parks, including the focal forest communities selected for this monitoring effort:

- Mangrove Forests are unique but low diversity coastal communities of south Florida and the Virgin Islands that are periodically flooded by high tides and storms. They are primarily composed of black mangroves (*Avicennia germinans*), red mangroves (*Rhizophora mangle*),

white mangroves (*Laguncularia racemosa*), and buttonwood (*Conocarpus erectus*). They are susceptible to sea-level rise, storm-driven impacts and inundation, salinity changes due to changes in freshwater inputs (hydroperiod), and times of hypersalinity due to storm surge inputs (Figure 2a).

- Coastal Hardwood Hammocks typically occur just landward of the mangrove shoreline and are typically dominated by a mixture of tropical tree species that are subjected to storm winds and storm surges. More specifically, Fan Palm and Mahogany Coastal Hardwood Hammocks are rare coastal hammock sub-communities of special interest due to the rare and endemic species located within.
- Pinelands are unique communities and are more like woodlands because they lack a closed forest canopy. The canopy trees, slash pines (*Pinus elliottii* var. *densa* in pine rockland communities and *Pinus elliottii* var. *elliottii* in sandy-soiled pine flatwoods), are widely spread apart from one another and are fire adapted. The slash pine communities occupy substrate from limestone karst to sandy soils. Numerous understory species are associated with, and often endemic to, slash pine communities. Pine forests are affected by changes in fire frequency and severity, changes in flood frequency and duration, increases in salinity in coastal areas, hurricane damage, disease, insects, and invasive plant species (Figure 2b).
- Cypress Forests in South Florida can be found as cypress strands, which are continuous forests that track depressional sloughs; cypress domes, which are smaller strands characterized by a monospecific overstory of bald cypress (*Taxodium distichum*) occupying bedrock depressions (Duever et al. 1979); or as dwarf cypress forests, a stunted form of Cypress Forest (Duever et al. 1979) that is not being monitored in this protocol implementation plan. All of these morphological features are still comprised of the same species: bald cypress. Cypress Forests are flooded most of the year. They are susceptible to changes in nutrients, fire frequency and severity, changes in flood frequency and duration, increases in salinity in coastal areas, hurricane damage, and invasive plant species (e.g., *Melaleuca quinquenervia*).
- Tropical Moist Forests in the Caribbean include two sub-communities: Gallery Moist Forests and Upland Moist Forests. Upland Moist Forests occur on mountainsides at higher elevations. Gallery Moist Forests occur in water runoff areas (or guts) that drain large upland areas. Both forest sub-communities are dominated by a diversity of very large tropical tree species which are influenced by changes in rainfall, changes in storm frequency, storm damage allowing exotic plant incursion, and herbivory by non-native fauna (e.g., deer, goats, and iguanas; Figure 2c).
- Tropical Dry Forests in the Caribbean are comprised of sub-communities such as Drought Deciduous Forests, Gallery Semi-Deciduous Forests, Semi-Deciduous Forests, and Manchineel Forests (Thomas and Devine 2005). Tropical Dry Forests are widespread in the U.S. Virgin Islands, occurring from the hillsides down to the ocean edge, with the canopy dominated by pigeon berry (*Bourreria succulenta*), black mampoo (*Guapira fragrans*), and

turpentine (*Bursera simaruba*), with an understory of *Eugenia* species and brisselet (*Erythroxylum brevipes*). Vegetation in Tropical Dry Forests is influenced by changes in rainfall, changes in storm frequency, exotic plant incursion, and herbivory by non-native fauna (e.g., deer, goats, and iguanas, Figure 2d).

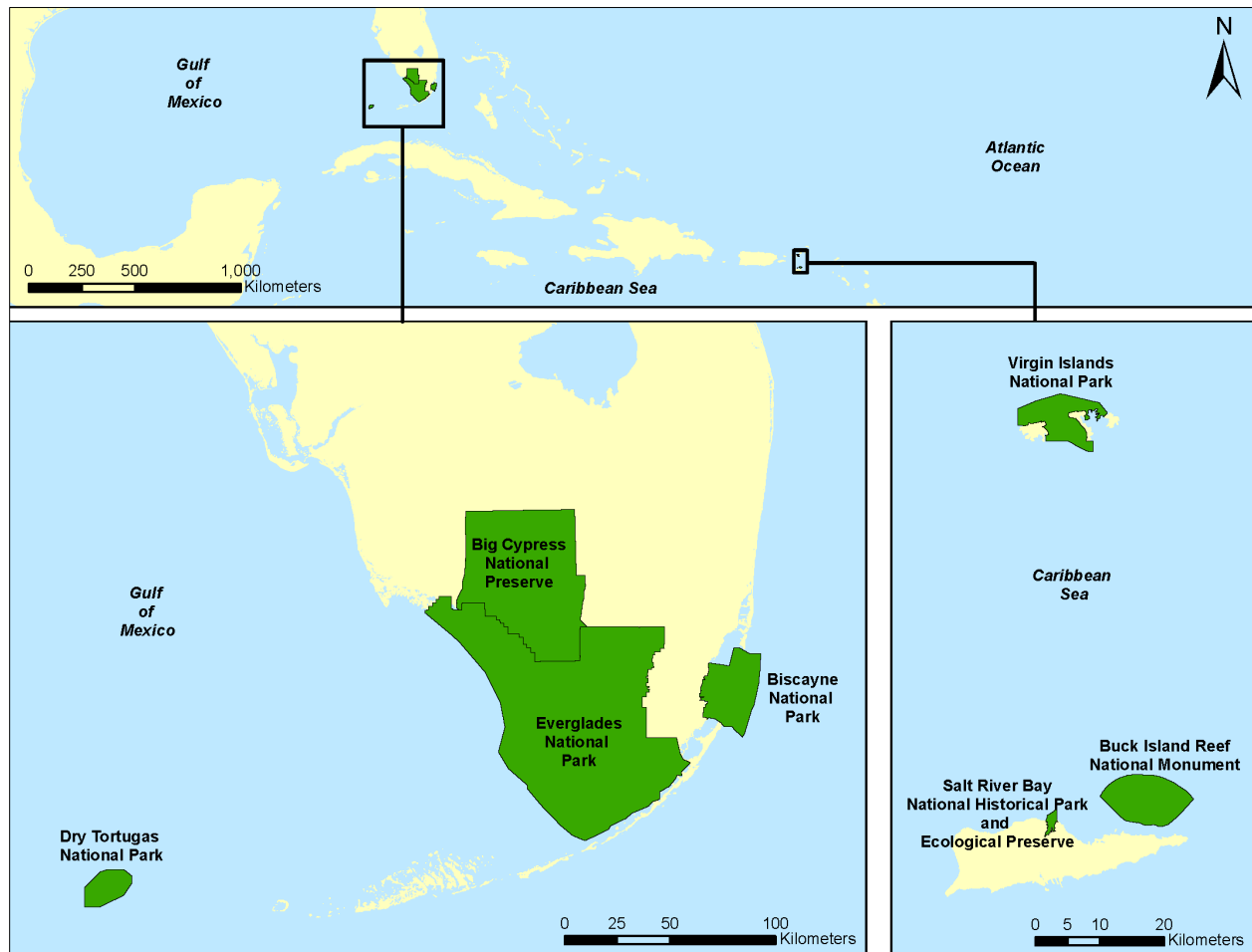


Figure 1. South Florida/Caribbean Network park locations. Green areas indicate park unit boundaries and extents. There are seven parks units in the network.

Table 1. Parks located within the South Florida/Caribbean Network.

Park Code	Park Name	Size (hectares)	State/ Territory	Ecoregion
BICY	Big Cypress National Preserve	295,388	FL	South Florida
BISC	Biscayne National Park	70,305	FL	South Florida
BUIS	Buck Island Reef National Monument	7,684	USVI	Caribbean
DRT0	Dry Tortugas National Park	26,541	FL	South Florida
EVER	Everglades National Park	619,404	FL	South Florida
SARI	Salt River Bay National Historical Park and Ecological Preserve	415	USVI	Caribbean
VIIS	Virgin Islands National Park	6,034	USVI	Caribbean



Figure 2. Plant community examples from South Florida/Caribbean Network parks. Upper left (a) Mangrove forest, Everglades National Park. Upper right (b) Pineland, Big Cypress National Preserve. Lower left (c) Tropical Moist Forest, Virgin Islands National Park. Lower right (d) Tropical Dry Forest, Salt River Bay National Historical Park and Ecological Preserve. Photography by: South Florida/Caribbean Network Inventory and Monitoring.

Source Protocol and How It Was Modified

The South Florida/Caribbean Network monitors focal forest vegetation communities following a version of the peer-reviewed and approved *Vegetation Monitoring Protocol for the Cumberland Piedmont Network, Version 1* (White et al. 2011), and its 2017 draft revisions (White et al. 2017). All CUPN standard operating procedures (SOPs) were reviewed, modified, and edited as necessary by the South Florida/Caribbean Network to ensure network relevance and integrity. Major changes have been made to the sampling design and analysis, primarily to accommodate the diverse and varied forest vegetation communities of the South Florida and Caribbean region. Modifications to the CUPN vegetation protocol are listed in Appendix A of this document. This appendix also includes

added justification for several of the most substantial changes. Descriptions of specific modifications plus minor procedural modifications are also provided in each SFCN standard operating procedure. Appendix B lists safety and training information.

There are nine major changes made to the CUPN protocol:

1. The South Florida/Caribbean Network sampling frame includes specific focal forest communities of interest in park units, rather than any forest or woodland. Focal forests are typically the dominant forest community in the park unit. There is limited edge and boundary spatial buffering that occurred to modify the sampling frame. Some additional communities of special management concern are monitored with one to three index sites per community.
2. The sampling design for the South Florida/Caribbean Network consists of plots stratified by focal forest communities within park units, rather than an unstratified design with forest plots spread evenly throughout the forest and woodland area of the entire park.
3. Sampling occurs within a single year across all plots of the same focal forest community within a park unit, rather than a portion of plots in every park each year.
4. Timing of sampling is from October to May, when it is safe to sample SFCN parks, rather than May to September like CUPN and other SER networks.
5. Analysis of vegetation and environmental metrics does not currently link to ecological integrity metrics in the South Florida/Caribbean Network because they have yet to be developed for ecosystems in South Florida or the Virgin Islands.
6. The South Florida/Caribbean Network made minor field modifications that are documented in each relevant SOP. This includes reducing the minimum DBH size for trees to 5 centimeters (2.0 inches [in]) from 10 centimeters (3.9 in). We modified the method for mapping tree locations, and we determine the forest community type using the specific definition from park vegetation map products instead of using the National Vegetation Classification type.
7. The South Florida/Caribbean Network does not collect soil samples or voucher specimens. We occasionally collect specimens for unknown identification; these are destroyed during processing.
8. The Cumberland Piedmont Network measures coarse woody debris fuels characteristics in their monitoring plots, while the South Florida/Caribbean Network has chosen to measure additional woody debris types, including fine woody debris and duff/litter.
9. The South Florida/Caribbean Network edited thirteen of the CUPN SOPs for SFCN specifics. We removed soil sampling and integrated two CUPN SOPs into two SFCN SOPs, edited one SOP from Gulf Coast Network, and added four new SFCN SOPs for network sampling design, safety, use of the distance range finder, and documenting revisions.

Section 2. Conceptual Framework for Monitoring

The South Florida/Caribbean Network designed its conceptual models using an adaptive management framework. This framework links causes of change (physical drivers and anthropogenic stressors) to the state of the environment and to management activities, and identifies areas of uncertainty that could affect decision-making. System drivers are major external forces that have large-scale influences on natural systems. These drivers can be either natural or anthropogenic and include things such as climate, tidal processes, freshwater and saltwater inputs, fire frequency, fire suppression, current and historical land use, and keystone species that make up the mosaic of conditions in which SFCN parks exist (Patterson et. Al 2008). The network's management-oriented conceptual model focuses on four broad categories of system drivers: physical systems, biological, anthropogenic stressors, and management actions. To facilitate the identification and prioritization of vital signs, the network divided the ecosystems in the South Florida and Caribbean parks into six ecological zones and developed conceptual models for each ecological zone.

Vegetated and non-vegetated systems have been classified in most SFCN parks through collaborative efforts with Florida International University, contract vendors, and network staff. South Florida vegetation has been classified using units defined by *Vegetation Classification for South Florida Natural Areas* (Ruthey et al. 2006), and Virgin Islands vegetation has been classified using units defined by *A Guide to Caribbean Vegetation Types: Preliminary Classification System and Descriptions* (Areces-Mallea et al. 1999). Specific focal forest community definitions can be found in each of the park vegetation mapping reports (a list of mapping reports is found in Table 2) and the focal forest community types can be found in Table 1 of SOP FVM02 *Sample Design and In Office Review* (Patterson and Londoño 2019a).

Table 2. Vegetation mapping reports and status for South Florida/Caribbean Network parks.

Park Code	Report Citation	Status
BICY	Ruiz, P. L., A. Lee, C. Thompson, I. Castillo, M. Guichardot, C. P. Perry, A. Arteaga Garcia, M. Foguer, M. C. Prats, E. Garcia, S. Lamosa, R. B. Shamblin, and K. R. T. Whelan. 2019. The Everglades National Park and Big Cypress National Preserve vegetation mapping project: Interim report—Eastern Big Cypress (Regions 5 & 6), Big Cypress National Preserve. Natural Resource Report NPS/SFCN/NRR— 2019/2035 . National Park Service, Fort Collins, Colorado.	Published
	Whelan, K. R. T., M. Prats, A. J. Atkinson, Avineon Inc., and The Institute for Regional Conservation. 20XX. Western Big Cypress National Preserve vegetation map. Natural Resource Technical Report – 20XX/XXXX.	In progress
BISC	Whelan, K. R. T., P. L. Ruiz, R. B. Shamblin, P. A. Houle, M. S. Ross, A. J. Atkinson, J. M. Patterson, J. Alonso. 2013. Biscayne National Park vegetation map project. Natural Resource Technical Report. NPS/SFCN/NRTR— 2013/774 .	Published
BUIS	Moser, J. G., K. R. T. Whelan, R. B. Shamblin, A. J. Atkinson, J. M. Patterson. 2010. Buck Island Reef National Monument, U.S. Virgin Islands, vegetation mapping project, 2009. Natural Resource Technical Report. NPS/SFCN/NRTR— 2010/293 .	Published
DRT0	Luciani, J. M., K. R. T. Whelan, R. B. Shamblin, R. M. Vargas, J. M. Patterson. 2011. Dry Tortugas National Park vegetation map, 2009. Natural Resource Technical Report NPS/SFCN/NRTR— 2011/469 .	Published
EVER	Schall, T.N., et al. 20XX. The Everglades National Park and Big Cypress National Preserve Vegetation Mapping Project: Interim report—Shark River Slough/Long Pine Key (Region 1). U.S. Army Corps of Engineers, Jacksonville, Florida.	In progress
	Ruiz, P. L., H. C. Giannini, M. C. Prats, C. P. Perry, M. A. Foguer, A. Arteaga Garcia, R. B. Shamblin, K. R. T. Whelan, and M. Hernandez. 2017. The Everglades National Park and Big Cypress National Preserve Vegetation Mapping Project: Interim report—Southeast Saline Everglades (Region 2), Everglades National Park. Natural Resource Report NPS/SFCN/NRR— 2017/1494 . National Park Service, Fort Collins, Colorado.	Published
	Ruiz, P. L., C. P. Perry, A. Arteaga Garcia, M. Guichardot, M. Foguer, J. Ingram, M. C. Prats, C. Pulido, R. B. Shamblin, and K. R. T. Whelan. 2020. The Everglades National Park and Big Cypress National Preserve vegetation mapping project: Interim report—Northwest Coastal Everglades (Region 4), Everglades National Park. Natural Resource Report NPS/SFCN/NRR—2020/XXXX. National Park Service, Fort Collins, Colorado.	In progress
SARI	Moser, J. G., K. R. T. Whelan, R. B. Shamblin, A. J. Atkinson, and J. M. Patterson. 2011. Salt River Bay National Historical Park & Ecological Preserve, U.S. Virgin Islands, Vegetation Mapping Project, 2009. Natural Resource Technical Report. NPS/SFCN/NRTR— 2011/448 .	Published
VIIS	Thanawastien, T., H. C. Giannini, J. M. Patterson, R. B. Shamblin, and K. R. T. Whelan. 2019. The National Park Service Vegetation Map of Virgin Islands National Park, St. John, USVI. Draft Natural Resource Technical Report.	In progress

Threats to SFCN Park Forest Resources

Forest communities encountered in SFCN parks are relatively stable entities with infrequent changes in composition, cover, and distribution. Focal forest community development is affected by a combination of physical features and processes that have historically been present (hydrology, salinity, fire, frost, topography, aspect, soil type, and depth [Duever 1979; Snyder et al. 1990; Gunderson 1994; Acevedo-Rodriguez 1996]). While they may contain areas of succession due to fire or other disturbance, as a whole they have historically been resilient to change (as evident from peat cores, type of soil development, or lack of soil development [Gunderson 1994]). Areas in early stages of succession due to disturbance are expected to revert to the same focal forest community if processes remain the same, thus, such stages are considered part of the focal community (Eggers 1879).

The primary natural disturbance processes in SFCN parks are fire and weather (e.g., hurricanes or drought). Anthropogenic disturbances, however, can pose a threat to natural processes, particularly as an additive effect to typical natural disturbances, and have the potential to alter the structure, function, and composition of vegetation communities. The most common anthropogenic disturbances include climate change, sea-level rise, fire suppression, landscape fragmentation, altered hydrology, nutrient pollution, artificially high levels of herbivory (deer, iguanas, hogs), and non-native species introduction. By monitoring focal forest plant communities, this protocol implementation plan can document the potential impacts of several key stressors that affect the integrity of the focal forest communities (Table 3). Stressors for parks within the South Florida/Caribbean Network that affect focal forest community dynamics include expansion of invasive exotic species and forest pests, increased herbivory from grazers, increased rates of natural and anthropogenic disturbance (e.g., frequency and intensity of coastal zone storms, fire suppression/regime shift, impacts from adjacent land-use and development), and changes in weather patterns and climate. Table 3 provides a list of stressors that affect SFCN park's focal forest resources and monitoring metrics that can address the impact of those stressors. Forest changes are occasionally brought about by multiple interactions among stressors. For example, along the Florida Gulf Coast, Desantis et al. (2007) has found that there is a synergistic effect of drought events and sea-level rise on the decline of coastal forests. These types of potential interactions will be considered as part of the overall analysis of changes in focal forest communities over time.

Table 3. Identified stressors affecting focal forest resources within South Florida/Caribbean Network parks and potential measures for vital signs monitoring. Information in this table is based on material taken from the vital signs monitoring plans of the South Florida/Caribbean Network (Patterson et al. 2008), Southeast Coast Network (DeVivo et al. 2008), Cumberland Piedmont Network (Leibfreid et al. 2005), and Gulf Coast Network (Segura et al. 2007).

Stressor Category	Issue for the Park	Potential Measures
Invasive Species	Invasive and exotic plant and animal species introduction and their consequent spread is a serious threat to forest vegetation. These species can displace native plants and change the structure, function and/or composition of vegetation communities.	• ¹Invasive species richness, coverage, and frequency. • ¹Change in native species richness/cover with increase in invasive species. • ¹Presence and coverage of grazing/browsing/rooting impact by exotic animals (Deer and pigs, US Virgin Islands). • ¹Presence of exotic plant pests.
Adjacent Land Use and Development	Urban expansion, residential and commercial land conversion, and road construction are increasing in areas surrounding many SFCN parks. Land conversion alters normal hydrologic patterns, disrupts dispersion of plants, and affects natural successional pathways in vegetation communities.	• Natural land use / land cover (DeVivo et al. 2018) • Converted land use / land cover (DeVivo et al. 2018) • Discharge, Hydrologic Index Tool metrics, fundamental daily streamflow statistics, and indicators of hydrologic alteration (DeVivo et al. 2018)
Extreme Weather Events	Low-elevation coastal wetlands are vulnerable to storm surges, and even inland systems can be impacted by wind and water disturbance events brought on by ocean-born tropical storms and hurricanes. Plants may be increasingly impacted by these events over time as global climates change and bring about potential shifts in frequency, magnitude, and duration of coastal storms.	• ¹Canopy coverage change • ¹Woody stem basal area and seedling/sapling density • ¹Windthrow occurrence • Storm frequency/magnitude (NOAA 2014) • Mangrove-March ecotone location (Moser et al. 2019)
Natural Fire Suppression and Fire Application	Some SFCN parks have an active prescribed-fire program for vegetation management and restoration, while many park management areas reflect a history of fire suppression. Both activities result in changing vegetation patterns on parks and an increasing need for information about impacted resources.	• ¹Changes in native plant species richness, coverage, and frequency • ¹Tree growth, mortality and recruitment • Fire Effects Monitoring program datasets • ¹Fuel load changes

¹ Indicates potential measures that have been selected for inclusion in the SFCN forest monitoring effort. The remaining listed measures are addressed through other monitoring initiatives by the National Park Service or partners.

Table 3 (continued). Identified stressors affecting focal forest resources within South Florida/Caribbean Network parks and potential measures for vital signs monitoring. Information in this table is based on material taken from the vital signs monitoring plans of the South Florida/Caribbean Network (Patterson et al. 2008), Southeast Coast Network (DeVivo et al. 2008), Cumberland Piedmont Network (Leibfreid et al. 2005), and Gulf Coast Network (Segura et al. 2007).

Stressor Category	Issue for the Park	Potential Measures
Climate Change	Anticipated long-term climate change is predicted to alter focal forest composition and overall species ranges at SFCN parks. Rising sea levels and salt water intrusion into inland/protected sites will impact lower coastal wetlands and flora. Also, changing precipitation and temperature are expected to alter vegetation communities in more xeric areas.	• ¹Changes in native plant species richness, coverage, and frequency • ¹Changes in vegetation composition, either from oligohaline and freshwater tolerant to saltwater tolerant species or from shade tolerant to shade intolerant species • ¹Tree growth, mortality and recruitment • Weather station datasets • Sea level using water level stations (NOAA 2018)
Visitor Use / Other Management Activities	Each park in the South Florida/Caribbean Network has its own goals and their resource management actions can affect forest communities. Management activities (e.g., invasive plant removal) may impact certain species, as may visitor impacts.	• ¹Changes in native plant species richness, coverage, and frequency • ¹Degree of disturbance from trampling, management action (e.g., mechanical/chemical treatments)

¹ Indicates potential measures that have been selected for inclusion in the SFCN vegetation monitoring effort. The remaining listed measures are addressed through other monitoring initiatives by NPS or partners.

Section 3. Measurable Objectives

This protocol is being implemented to monitor the status and trends of ecological health for focal forest communities, with the goal of informing management decisions affecting those systems. Ecological health is defined as “the condition of an ecosystem in which processes and functions are adequate to maintain diversity of biotic communities commensurate with those initially found there.” (as defined in White et al. 2011). This monitoring effort focuses on specific focal forest communities within each park unit. The monitoring effort does not target all forests or other types of vegetative areas within SFCN parks.

There is currently one primary monitoring objective for this protocol implementation plan:

Detect meaningful changes in species composition and vegetation structure within specific focal forest communities in SFCN parks, and determine whether these changes are correlated with trends in key stressors.

In addition to the focal forest communities, the network will monitor one to three index sites in additional forest communities of special concern. These communities are spatially limited and the index sites will serve as indicators of what may be occurring, but without the sample size or statistical design needed to detect meaningful changes in the communities.

A future objective associated with this plan is to “*determine the ecological health of targeted forest communities of SFCN parks with respect to that community’s reference condition.*” This approach has not yet been developed, but the network hopes to work with partners over the next several years to define ecological integrity metrics of targeted communities of management concern. When metrics have been defined, this will be included as a second primary objective.

These objectives are adapted from the CUPN protocol (White et al. 2011), which is based on a number of monitoring approaches, including the Carolina Vegetation Survey (CVS; Lee et al. 2008), the USDA Forest Service Forest Inventory and Analysis program (USDA 1999), ecological integrity criteria developed by NatureServe and NPS (Faber-Langendoen et al. 2006), and three other inventory and monitoring Programs in the eastern United States (Sanders et al. 2006; Perles et al. 2007; Tierney et al. 2016). The CUPN objectives have been modified to focus on specific focal forest communities rather than on any forested habitats, and to clarify that “vegetation community measures” mentioned by Cumberland Piedmont Network will be restricted to forest species composition and structure. We follow the Northeast Temperate Network in defining a statistical target of being able to detect a 40% change in specific metrics of species composition and vegetation structure over 12 years (15 years for South Florida/Caribbean Network) and within a vegetation community (focal forest community), with a power of 80% and chance of false positive of 10% (Tierney et al. 2016).

The vital sign selection process for the South Florida/Caribbean Network highlighted the importance of forest species diversity and functional plant communities with intact disturbance regimes as natural resources critical to the parks (Patterson et al. 2008). Focal forest communities can serve as

an integrated measure of ecosystem health by exhibiting changes influenced by alterations in climate, soils, and disturbance patterns. In addition, this protocol implementation plan supports invasive plant management by providing information about the prevalence and occurrence of invasive species within these focal forest areas. This information could help parks understand ecological impacts of these species.

To detect significant changes in species composition and forest structure, the South Florida/Caribbean Network has chosen a set of measures that can be monitored at regular intervals and used to report on change over time. Some of these measures relate to key stressors, others relate to specific biotic attributes of the plot, and all can be compared across sampling events to determine whether there is significant change between sampling periods.

Certain measures that have been chosen to address the primary monitoring objective can be combined and used to summarize ecosystem health through an ecological integrity scoring system. By measuring taxonomic, structural, and demographic features, we can look at whether the ecosystem's parameters fall within expected or accepted norms and ranges of variability. To date, however, the metrics and associated thresholds have not been developed for forest communities across SFCN parks. Over the next several years, the network will work with partners to define metrics and thresholds that will serve as indicators of ecological integrity. These metrics will be easily explained through ratings (i.e., good, fair, or poor) and can be explicitly linked back to park management practices.

Section 4. What's Being Measured and How

The South Florida/Caribbean Network monitors forest vegetation in fixed plots that are resampled once every five years. Focal forest plots are selected using a continuous draw of plot centroids across a park's focal forest community types via the generalized random-tessellation stratified (GRTS) sampling methodology (Stevens and Olsen 2004) to create a spatially-balanced, random set of monitoring sites for each of the focal forest communities within each SFCN park. The sampling design framework for the South Florida/Caribbean Network's forest vegetation monitoring begins with the selection of focal forest community polygons from the most recent vegetation maps. These polygons represent the spatial coverage of focal forest communities at the time of map creation and are buffered by 15 meters (49.2 feet [ft]) to ensure that plots do not contain roads, trails, buildings, park inholdings, steep (greater than 30°) slopes, and park boundaries. In Big Cypress NP there is an additional rule that plots must be within 1,000 meters (3,281 ft) of a road or a trail to limit travel time within this large park. The buffered vegetation map polygons represent the sampling frame of vegetation monitoring in SFCN parks; see SOP FVM02 *Sample Design and In Office Review* (Patterson and Londoño 2019a).

There are three main advantages to a GRTS design. First, the sample points generated by GRTS are spatially balanced, so there is generally uniform dispersion of sampling sites over the area of interest. This ensures that all areas included within the sampling frame are represented. Second, the GRTS design allows for flexible sample size, such that sites can be added to or excluded from the sampling plan, while still maintaining the spatial balance and without compromising the integrity of the overall design. For instance, if "plot #2" is rejected using established decision rules for plot selection, we can simply pick the next number on the list of plots not yet assigned to continue to have a random, spatially balanced sample. This allows potential sites to be rejected if they are determined inappropriate, or additional sites to be added if funding is increased and additional plots are needed to meet our objectives. Finally, the GRTS method eliminates site selection bias, because sampling points are randomly chosen among all possible points within a systematic grid. The GRTS design also offers additional flexibility for post-stratification of plots based on other user-defined criteria, such as forest community type or age-class (Stevens and Olsen 2004).

The SFCN protocol uses, with a few modifications, the plot layout and field sampling methods that were developed by the Cumberland Piedmont Network (White et al. 2011). Links between monitoring elements, sampling methods, and data outputs are provided in Table 4, adapted from the vegetation protocol developed by the Gulf Coast Network (Carlson et al. 2018). Many of the SOPs have been modeled from the terrestrial vegetation protocol implementation plan developed by the Southeast Coastal Network (Boyle et al. 2019).

Table 4. Monitoring elements, sampling methods, and data collected for the SFCN Forest Vegetation Monitoring Protocol (table adapted from the GULN and SECN vegetation protocol implementation plans, Carlson et al. 2018 and Boyle et al. 2019).

Monitoring Objective	Element	Sampling Method	Data Collected
Objective 1— status and trends	Vascular plant species richness	Count the number of vascular plant species encountered in eight 1 m ² (1 × 1 meter) and eight 10 m ² (3.16 × 3.16 meter) nested subplots, and four 100 m ² (10 × 10 meter) modules. These data can be combined to encompass the full 400 m ² (20 × 20 meter) plot.	The total count of species in a sampling unit is species richness. Data can be summarized as averages across nested subplots, modules, or the 400 m ² plot. There are separate counts of native species and invasive species.
Objective 1— status and trends	Vascular plant species relative frequency and constancy	Record frequency by documenting species occurrence in four 100 m ² (10 × 10 meter) modules.	For each plot, relative frequency is estimated at one scale per species. At the largest scale, the frequency is the number of 100 m ² modules that contain at least one individual of that species, and then dividing that by the total number of modules (4). Constancy is the frequency of occurrence of a species within a specified group (e.g., forest community) of plots.
Objective 1— status and trends	Woody stem (tree, ≥ 5 cm DBH) basal area, density, health condition, mapped location, growth, mortality, and recruitment	Record diameter and health condition (e.g., pest presence) of each live and dead woody stem ≥ 5 centimeter DBH (1.37 meters above the ground) within each of the four 100 m ² (10 × 10 meter) modules and document their spatial location on the plot.	Basal area is calculated for each species of tree within the entire plot, from DBH values from individual trees; density is a count of trees/plot, separated by species. The status (e.g., presence of tree pest and disease) for each standing individual tree is ancillary data and will eventually be used to calculate a forest/woodland health condition. Tree growth, mortality and recruitment will be calculated based on repeat sampling data.
Objective 1— status and trends	Woody stem (sapling, ≥ 1.37 m tall, < 5 cm DBH) basal area and density; woody stem (seedling, < 1.37 m tall) density	Record diameter class and species of each sapling in eight 10 m ² (3.16 × 3.16 meter) nested subplots; record the height class and species of each seedling in eight 1 m ² (1 × 1 meter) nested subplots.	Basal area is calculated for each species of sapling within the 10 m ² subplots and standardized to the plot area, from DBH values from individual saplings; density is estimated number of saplings or seedlings on the plot, based on the counts of saplings and seedlings standardized to the plot area and separated by species.

Table 4 (continued). Monitoring elements, sampling methods, and data collected for the SFCN Forest Vegetation Monitoring Protocol (table adapted from the GULN and SECN vegetation protocol implementation plans, Carlson et al. 2018 and Boyle et al. 2019).

Monitoring Objective	Element	Sampling Method	Data Collected
Objective 1— status and trends	Fuel loads of downed woody material	Record the density and decay classes of coarse woody debris, density of fine woody debris and depths of litter, duff, and fuel bed strata across the ground cover of three 25-meter (82-ft) transects.	Density or depth of each downed woody material category (coarse and fine woody debris, litter, duff, fuel bed) is calculated into a fuel load (tons/acre) estimate for the three transects
Objective 1— status and trends	Threat to Plant Community	Estimate the presence and areal coverage of the following: 1. grazing/rooting impact by animals. 2. exotic plant pests. 3. degree of disturbance from trampling, trail proximity, management action (e.g., mechanical/chemical treatments). 4. fire suppression + fire history	Percent cover is estimated for the entire plot for each threat and disturbance observed within the plot. Fire history data are acquired from the park and regional fire ecologists.
Ancillary Data & Future Objective 2— reference condition comparison	Status of cover class values of vascular species and strata	Estimate percent cover for all species present in each 100 m ² (10 × 10 meter) module, and for each stratum present (tree, shrub, herbaceous) in the full 400 m ² (20 × 20 meter) plot.	Percent cover is estimated for each species and stratum following the Carolina Vegetation Survey cover scale: < 0.1%, 0.1–1, 1–2, 2–5, 5–10, 10–25, 25–50, 50–75, 75–95, 95–100% (Peet et al. 1998). A mean cover class will be reported for each plot.
Ancillary Data	Vegetation classification	Identify vegetation type for the plot using classification keys developed for each SFCN park.	Community designation based on the vegetation map classification keys.
Ancillary Data	Site characteristics	Estimate plot geomorphology (slope, aspect, landform, topographic position), and percent cover of water on the plot for the entire plot.	1. Slope (degrees) 2. Aspect (compass bearing) 3. Water (percentage) 4. Topographic position and landform are qualitative assessments.
Ancillary Data	Photo points	Three digital images are made of each plot.	Three digital image files.

Overview of Methods

Preparation and Plot Set-Up

The vegetation monitoring field crew prepares for monitoring activities well in advance of each field season following the steps detailed in SOP FVM01 *Field Season Preparation* (Shamblin 2019a). All plots within a given focal forest community type or forest of special management concern within a park are visited during a single 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 GPS device. The field crew locates and places the remaining six permanent markers using measuring tapes and a compass. The plot layout is shown in Figure 3. These and related methods are described in SOP FVM03 *Plot Evaluation, Plot Establishment, and Return Visits* (Shamblin 2019b). Plot establishment data and a plot layout diagram are recorded on *SFCN Veg Form 1—Vegetation Plot Establishment* which is included in the Appendices of SOP FVM03.

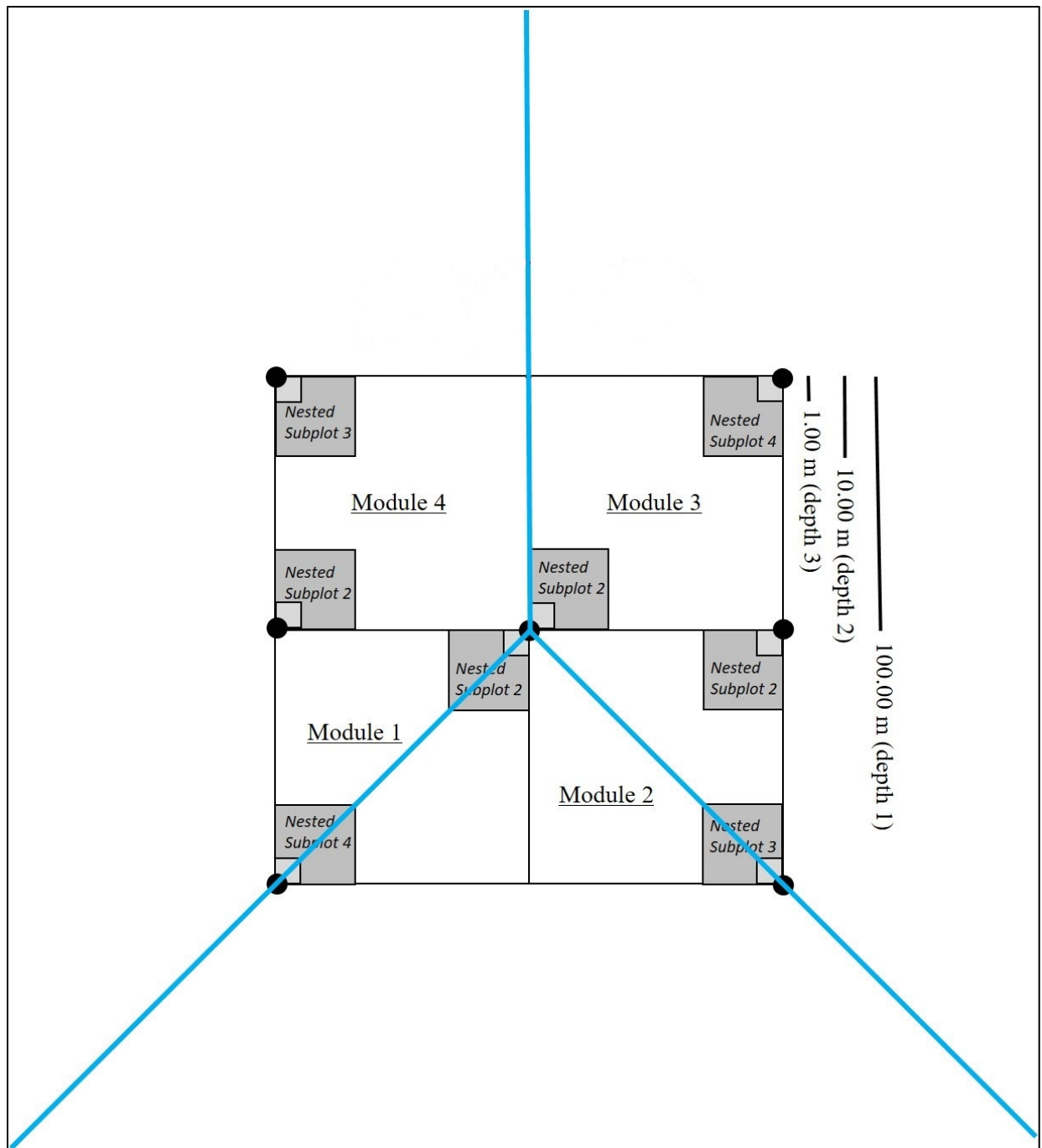


Figure 3. The standard South Florida/Caribbean Network forest sampling unit, which includes a 20 × 20-meter (65.6 × 65.6-ft) modified Carolina Vegetation Survey plot (black lines; Peet et al. 1998) and three 25-meter (82-ft) fuel transects (blue lines). Black dots along the plot perimeter mark where rebar stakes will be located.

Field Sampling Methods

Once the plot location has been determined to be acceptable (see SOP FVM03 *Plot Evaluation, Plot Establishment, and Return Visits* [Shamblin 2019b]), the field crew completes eight major tasks, including (1) confirmation of forest community type, (2) site characteristics, (3) plot photo points, (4) tree DBH, condition, and canopy closure estimates, (5) tree spatial locations so a map can later be generated, (6) species identification, number of species present, and cover measurements, (7) seedling and sapling count, and (8) fuel load estimates. Certain site characteristic elements (e.g., landform, terrain shape) are only taken during the first sample event directly following plot establishment. Geomorphology measures are stable over time and can be used to compare SFCN monitoring plots with reference conditions from other databases to begin addressing the planned future objective of determining the ecological health of the focal communities.

For task (1), the field crew determines if the forest is the desired community type based on vegetation maps created for each park. If the forest is not the desired community type, then the site is rejected and the next point on the focal forest community list (next GRTS number) is visited. The forest type for each plot will be determined upon each plot visit. If the forest type has changed but the plot is still forested, then the plot will be sampled and the change in forest community will be noted. If the plot becomes unforested, then the plot will be dropped and another site will be chosen from the next GRTS location. Refer to the relevant vegetation map product for the specific vegetation community descriptions. Full instructions are provided in the SOP FVM03—*Plot Evaluation, Plot Establishment, and Return Interval* (Shamblin 2019b). Data are recorded on *SFCN Veg Form 1—Vegetation Plot Establishment* (included with SOP FVM03).

For tasks (2) and (3), the crew records site characteristics such as slope, aspect, basic hydrological condition, terrain shape, and indicators of disturbances to the plot. These methods are described in SOP FVM03. The crew takes three photo point photographs for the plot, as described in SOP FVM04 *Plot Photo Points* (Shamblin 2019c). Site data are recorded on *SFCN Veg Form 2—Site Characteristics* (included in SOP FVM03) and photo point data are recorded on *SFCN Veg Form 3—Plot Photo Points and Canopy Closure Measures* (included in SOP FVM03 and SOP FVM05).

For tasks (4) and (5), the crew identifies all woody stems within the 20 × 20-meter plot that are ≥ 5 centimeters (2.0 in) DBH to the highest level of taxonomic accuracy possible. Each stem is tagged and its spatial location is recorded. In addition, two of the trees near plot center will also be tagged with stainless steel plot identification tags to assist in locating plot center on future plot visits. For live trees, crews record DBH, status (i.e., alive, no longer in sample, etc.), crown class, vigor, dieback, damage, foliage condition, and foliage percent; for dead trees, crews record the DBH, decay class, and estimated height. Finally, a spherical densiometer is used to estimate canopy closure across the plot. SOP FVM05—*Canopy Closure and Stand Height Measurements* (Shamblin 2019d) provides specific details about what data are recorded. Instructions for how to deal with forked trees or trees that otherwise require a different DBH measurement are in SOP FVM06 *Tree measurements* (Shamblin 2019e). Tree diameter data and spatial locations (distance and bearing from plot center) are recorded on *SFCN Veg Form 7—Tree Measurements* and canopy closure estimates are recorded on *SFCN Veg Form 3—Plot Photo Points* (included with SOP FVM03).

Tasks (6) and (7) require the development of species lists across nested subplots. The field crew begins by recording the presence of vascular plant species that are rooted within the 1×1 meter (3.3 $\times$ 3.3 ft) subplot in corner 2 of module 1 (see Figure 3); next the crew tallies the woody plant seedlings that are between 5 and 137 centimeters (2–54 in) within the subplot. The subplot is then extended to 3.16×3.16 meter (10.4 square feet) and any vascular plant species that was not located in the 1×1 meter subplot is recorded; woody plant saplings that are greater than 137 centimeters (53.9 in) in height and less than 5 centimeters (1.97 in) DBH are tallied in this extended subplot. These steps are repeated in corner 4 of module 1. Once these two nested subplots in corners 2 and 4 have been sampled, the remaining area of the module is searched for any new vascular plant species that are either rooted in or overhanging the module. Finally, an aerial cover class value is estimated at the module-scale for each species rooted in or overhanging the module. These steps are repeated in module 2 (nested subplots 2 and 3), module 3 (nested subplots 2 and 4), and module 4 (nested subplots 2 and 3). Full instructions are provided in SOP FVM07—*Species Diversity and Seedling/Sapling Measurements* (Shamblin 2019f). Diversity and species cover data are recorded on *SFCN Veg Form 5—Species Diversity* while seedling and sapling measurements are recorded on *SFCN Veg Form 6—Seedling/Sapling Measurements* (included with SOP FVM07).

For task (8), the field crew records the condition of coarse and fine woody debris, duff depth, litter depth, and fuel bed depth along three 25 m transects originating from the plot center (see Figure 3). Full instructions are provided in the SOP FVM08—*Woody Debris* (Prats 2019a). Data are recorded on *SFCN Veg Form 4—Woody Debris* (included with SOP FVM08).

Data Entry and Management

Field data are recorded on paper datasheets. Within three weeks following field work, data are entered into the SFCN forest vegetation database. Data management, quality assurance (QA) and quality control (QC) procedures are explained in the SOP FVM010—*Data Quality Assurance and Quality Control* (Patterson and Londoño 2019b) and SOP FVM11—*Data Management: Procedures upon Return from the Field* (Patterson and Londoño 2019c). See also Section 6, Data Management, Analysis, and Reporting.

A customized Microsoft Access relational database, based on the CUPN forest vegetation database, will be used for storage and manipulation of project data. This database will comply with current IMD database standards and best practices. The SFCN data manager will be responsible for future development and maintenance of the application, and will seek partnership opportunities with the CUPN and SECN networks.

Additional Operational Notes

Many SFCN parks have indicated strong interest in participating in the focal forest sampling events when park staff are available. Such participation will greatly enhance efficiency and shorten overall sampling time. However, as participation is not a park obligation, the SFCN sampling schedule is developed annually under the expectation that SFCN staff or cooperators complete all field work on their own.

Section 5. Sampling Design and Monitoring Schedule

The Gulf Coast Network (Carlson et al. 2018) and the Northeast Temperate Network (Tierney et al. 2016) used a minimum sample size allocation of ten plots on a per park basis. The SFCN will sample from eight to thirty plots per park focal forest community, and 10 to 54 total plots per park (Table 5). One to three index sites are placed within spatially limited forest communities of special management concern within BUIS, DRTO, SARI, and VIIS.

The network will sample all plots within a focal forest community or forest community of special management concern within a park unit within a given year. All forest plots will be monitored once every five years (Table 5). The original CUPN vegetation monitoring protocol used a two-year rotating panel design to sample eight plots per park per year at most of their parks, and a four-year rotating panel design for the two largest parks (White et al. 2011). The current CUPN sampling is similar to our five-year rotation (B. Moore, CUPN, personal communication). The SFCN rotation samples several communities across several parks every year. For example, in year one the South Florida/Caribbean Network will sample the BICY Hardwood Hammocks, BISC Mangroves, and SARI Tropical Dry Forests (Table 5). The parks in the network are spread apart geographically (see Figure 1) and accessing all seven parks within a given sample year would not be financially or logistically feasible. To balance cost and effort across years we have developed a schedule that balances local travel with more expensive sampling trips. Sampling all plots from a focal forest community within a park unit within a year means that for a given community, different plots will not have differences based on annual variation. This design increases within-cycle similarity across plots, but with the cost of decreasing the between-cycle similarity. Initially this may make it more difficult to detect trends, but it will make it easier to describe vegetation status within a given park and year. The proposed sampling matrix (Table 5) includes focal forest communities (typically the dominant forest type) and forest communities of special management concern (identified by the park managers), typically identified due to a pressing concern (sea level rise, wildlife usage, etc.). The panel design balances logistical constraints due to staffing, sampling costs, and workload from other SFCN vital signs.

Table 5. Timeline of forest plot monitoring activities in the South Florida/Caribbean Network from fall 2019 (beginning of Panel 1) to spring 2024 (end of Panel 5). Full forest type names are as follows; Dry Tropical Forests (includes the Manchineel Forests), Mangrove Forests, Tropical Moist Forests (includes Gallery Moist Forests and Upland Moist Forests), Coastal Hardwood Hammocks, Cypress Forests, and Pinelands.

Park	Panel 1	Panel 2	Panel 3	Panel 4	Panel 5
BUIS	–	1 Manchineel ^{1,2}	–	–	–
SARI	8 Dry	–	–	2 Mangrove ^{1,2}	–
VIIS	–	8 Moist “Gallery”	–	3 Mangroves ¹ 10 Dry	8 Moist “Upland”
DRTO	–	–	–	2 Mangrove ¹	–
BISC	8 Mangrove	–	–	–	8 Coastal
EVER	–	16 Cypress	–	8 Coastal	–
BICY	12 Hardwood	–	30 Cypress	–	12 Pineland
# Plots	28	25	30	25	28

¹ Forest communities of special management concern.

² These plots are sampled during the same trip as the SFCN Soil Elevation Protocol to reduce travel and staff cost.

Sample Size Determination and Power Analysis

The target number of plots for each focal forest community within a park was based on: (1) review of three historical, long-term data sets in three types of forest communities within the network (Smith et al. 1994; Bennett 1995; Oberbauer et al. 1996;), (2) pilot forest sampling work which sampled eight plots in Salt River Bay NHP&EP in a number of forest types, and (3) consultation with a National Park Service SFCN forest sampling review panel. The review panel emphasized that, in the absence of a robust pilot data set, five plots per community type would be an absolute minimum. The panel advised more plots, particularly in heterogeneous or geographically widespread communities, and said that the sample size determinations should be reviewed after initial data collection. The South Florida/Caribbean Network established a minimum number of eight plots per focal forest community type of interest. We estimate that field crews can monitor 25 to 30 forest plots per year for a total of 136 plots (excluding QA/QC plots) across the five-year rotation (Table 5). The South Florida/Caribbean Network allocates more plots in areas with more area coverage of focal forest (Table 6). We aimed for between one and twenty-five plots per 100 hectares (247 acres [ac]) of focal forest sample frame area for each park and park unit, which was achieved for all but the small focal forest (EVER Coastal Hardwood Hammock) and for focal forest communities in Big Cypress National Preserve (Table 6). The current minimum number of plots will be reassessed in subsequent power analyses, once two iterations of data have been collected for all SFCN parks included in this protocol.

Table 6. Plot allocation within Focal Forest Community types of parks within the NPS South Florida/Caribbean Network [ha—hectare].

Park	Focal Forest Community	Focal Forest Community Code	Target Area ¹	Sample Frame Area	Percent ²	Sample Size ³	Plot / 100 ha ⁵	Panel(s)
BICY	Cypress Forest	CYP	83,740	43,452	52%	30	0.07	3
BICY	Hardwood Hammock	HAM	7,821	4,618	59%	12	0.26	1
BICY	Pineland	PIN	38,090	27,242	72%	12	0.04	5
BISC	Coastal Hardwood Hammock	CHH	709	667	94%	8	1.2	5
BISC	Mangrove Forest	MAN	764	743	97%	8	1.08	1
EVER	Coastal Hardwood Hammock	CHH	13	13	100%	8	61.54	4
EVER	Cypress Forest – East	CFE	122	122	100%	8	6.57	2
EVER	Cypress Forest – West	CFW	494	494	100%	8	1.62	2
SARI	Tropical Dry Forest	TDF	63	39	62%	8	20.45	1
VIIS	Tropical Dry Forest	TDF	1,116	480	43% ⁴	8	1.67	4
VIIS	Tropical Moist Forest	TMF	216	95	44% ⁴	8	8.42	2, 5

¹ Estimated habitat (target population) area in hectares

² Estimated percentage of target area in sample frame

³ Total number of plots

⁴ Rough estimate; revised GIS steps will be completed prior to year two sampling

⁵ Plots per 100 ha of sample frame area

The network range of 25–30 plots per year (Table 5) is about one-fourth of the number of plots targeted in the vegetation monitoring protocol of the Cumberland Piedmont Network (White et al. 2011), which targeted 112 plots per year. Due to the extremely large size of some of the park units in the network (e.g., Big Cypress National Preserve is more than 290,000 hectares [1,120 square miles]) and difficult access to several parks, a reduction in sampling effort is needed to be sustainable in the long term. The network also has additional protocols (Periphyton, Corridors of Invasiveness, Soil Elevation Table [SET], and Mangrove-Marsh Ecotone) that will require the time of the same crew. Additionally, the Cumberland Piedmont Network samples any forests and woodlands across a park unit while the South Florida/Caribbean Network sampling is targeted towards focal forest

communities. When sampling within specific communities instead of park-wide, plots within a community are more similar to each other than plots from a park-wide sample. This reduced plot variability should make it possible to detect trends within a given community at a lower sample size than park-wide trends can be detected at CUPN parks. The Cumberland Piedmont Network initially allocated 16 plots per park for smaller parks and 32 plots per park for larger parks, though these totals were later increased to 20 and 60 respectively (B. Moore, Cumberland Piedmont Network, as cited in Boyle et al. 2019). South Florida/Caribbean Network, in contrast, has eight to twelve plots in each focal forest community, with the exception of 30 plots in BICY extensive Cypress Forest community. We are planning on sampling 128 plots, plus eight additional plots in forest communities of special management concern.

Like the Cumberland Piedmont Network, the South Florida/Caribbean Network also randomly chooses a portion of plots sampled within a given year (approximately 5% or two plots per year) to be resampled in that same year to monitor data quality and within-year sampling consistency. These quality control resampled plots are determined at the beginning of each field season.

Spatial Allocation

The sampling design for the South Florida/Caribbean Network's forest vegetation monitoring begins with the selection of focal forest community polygons from the most recent vegetation maps (see Table 2). Focal forest names are provided in Table 6. These polygons represent the spatial coverage of focal forest communities and are buffered by 15 meters (49.2 ft) to remove areas too close to roads, trails, buildings, park inholdings, steep (more than 30 degree) slopes, the edges of polygons, and park boundaries. In Big Cypress NP, there is also an additional rule that plots must be within 1,000 meters (3,280 ft) of a road or a trail to limit travel time within this large park. These buffered vegetation map polygons represent the sampling frame of vegetation monitoring in SFCN parks and are reported by focal forest type in Table 6.

The selection of plots to sample, with the number for each focal forest community pre-determined (see Sample Size Determination and Power Analysis), utilizes the Generalized Random Tessellation Stratified (GRTS) sampling methodology. The selection of plot centroids for each focal forest community was based on a continuous draw of points across each sampling frame, utilizing the GRTS sampling methodology to maintain spatial balance. The GRTS technique uses reverse hierarchical ordering to map two-dimensional space (e.g., locations of plots in a park) into one-dimensional space, by giving each plot an ordered spatial address. Then, the program uses restricted randomization to order the addresses into a random, spatially balanced list of plots (McDonald 2004; Stevens and Olson 2004).

The GRTS technique for the SFCN forest plot allocation is performed in the statistical program R v3.5.1, utilizing the *spsurvey* library (Kincaid and Olsen 2017). Shapefiles of plot centroid points are produced for each focal forest type; these points are placed in a spatially balanced GRTS order as described above. Any consecutive sub-sample of points on this list maintains spatial balance. Additional plot centroid points are provided by the GRTS draw, which represent alternate (or replacement) points should any of the original selected points need to be excluded from sampling or

if monitoring needs to be expanded in the future. Further details can be found in SOP FVM02 *Sample Design and In Office Review* (Patterson and Londoño 2019a).

After generating the ordered list of GRTS points for each of the focal forest communities within the SFCN parks, maps of the primary (selected) and overdraw (alternate) plot locations are reviewed internally. The highest resolution and most recent aerial imagery is used to determine if any plots fall in exclusion areas. Reasons for plot exclusion include:

- any of the plot occurs within marsh habitat or open water
- any of the plot falls outside the focal forest community as defined in Table 1 of SOP FVM02 *Sample Design and In Office Review* (Patterson and Londoño 2019a)
- sampling the plot would pose a safety risk (e.g., plot occurs along a cliff face or abundance of unstable snags)
- any of the plot occurs on privately owned land
- the plot includes non-vegetated areas (e.g., transportation corridors, built-up lands, roads, swamp buggy trails, or beaches)
- the plot includes heavily used trails
- the plot includes sensitive archaeological resources or cultural sites
- the plot is inaccessible (estimated travel to and from the plot, and sampling the plot, cannot be accomplished in a 10-hour day) by boat or foot travel

Finally, during the initial plot visit the field crew reassesses the plot to verify that the plot does not fall within an exclusion area. If any of the above criteria are observed in the field the plot is rejected. When plots are rejected for any reason, the next unused plot number in the ordered list is chosen to replace it.

Temporal Allocation

Field work for this protocol is conducted in fall to spring (October–May), when sampling is safest (cooler temperatures, less humidity, lower standing water, less frequency of thunderstorm, and fewer hurricane chances) and the forests are accessible. All seven network parks are sampled according to a five-year monitoring cycle (Table 5); one to four parks are sampled each year, followed by analysis and reporting of data from the sampled focal forest communities at the end of each sampling year. When resampling plots, the goal is to sample a given plot within two weeks of the original sample date to reduce the confounding of seasonal variation with annual variation. As a result, focal forests are revisited in a consistent order over time.

In the first sampling panel, Big Cypress National Preserve (BICY) Hardwood Hammock plots, Biscayne National Park (BISC) Mangrove plots, and Salt River Bay National Historical Park and Ecological Preserve (SARI) Tropical Dry Forest plots will be sampled. In the second sampling panel, Everglades National Park (EVER) Cypress Plots, Virgin Islands National Park (VIIS) Tropical Moist “Gallery Forest” plots, and the Buck Island Reef National Monument (BUIS) Tropical Dry “Manchineel” plot will be sampled. BICY Cypress plots will be sampled in the third panel. In the

fourth sampling panel, EVER Coastal Hammock plots, Dry Tortugas National Park (DRTO) Mangrove plots, VIIS Tropical Dry Forest plots, VIIS Mangrove plots, and SARI Mangrove plots will be sampled. In the fifth sampling panel, BICY Pineland plots, BISC Coastal Hammock plots, and VIIS Upland Forest plots will be sampled (Table 5).

A summary of the temporal design and scale of analysis for each monitoring element is provided in Table 7. Table 8 provides a timeline of fieldwork and reporting over the next 15 years.

Table 7. Monitoring elements, temporal design, and scale of analysis at South Florida/Caribbean Network parks as part of the protocol for forest vegetation monitoring.

Element	Temporal Design	Scale of Analysis
Vascular plant species richness	Recorded for all plots in a focal forest community type in a single sampling season, conducted once every five years.	The plot is the sampling unit for analysis. Richness is represented as a total for the plot. These data are summarized for each forest community once every five years. Species accumulation curves (incorporating subplot to module scales) or similar methods may be used to estimate undersampling bias and confidence intervals. Trend analyses require three sampling events per plot and will be performed separately for different forest community types within each park.
Vascular plant species relative frequency and constancy	Recorded for all plots in a focal forest community type in a single sampling season, conducted once every five years.	The plot is typically the sampling unit, but nested subplot or module scales may be used for analyzing common species or guilds with high relative frequencies, since change will be more detectable when frequency proportions are at intermediate levels. Summaries and analyses typically focus on plant guilds or focal, common species. Data for each forest community are summarized after each sampling event, once every five years. Trend analyses require at least three sampling events per plot and will be performed separately for different forest community types within each park.
Woody stem (tree, ≥ 5 centimeters DBH) basal area, density, health condition, mapped location, growth, mortality, and recruitment	Recorded for all plots in a focal forest community type in a single sampling season, conducted once every five years.	The plot is the sampling unit. Summaries focus on individual focal, common species. Data for each forest community are summarized after each sampling event, once every five years. Trend analyses require at least three sampling events per plot and will be performed separately for different forest community types within each park. Because it will take four sampling events to obtain three estimates of tree growth, mortality, and recruitment, trends analyses for these elements will not begin until after the fourth sampling event.
Woody stem (sapling, <5 cm DBH) basal area and density; woody stem (seedling, <1.37 m tall) density	Recorded for all plots in a focal forest community type in a single sampling season, conducted once every five years.	The plot is the sampling unit. Summaries focus on individual focal, common species. Data for each forest community are summarized after each sampling event, once every five years. Trend analyses require at least three sampling events per plot and will be performed separately for different forest community types within each park.
Woody debris	Recorded for all plots in a focal forest community type in a single sampling season, conducted once every five years.	The set of three 25-meter transects is the sampling unit. Summaries focus on woody debris. Data for each forest community are summarized after each sampling event, once every five years. Trend analyses require at least three sampling events per set of transects and will be performed separately for different forest community types within each park.

Table 7 (continued). Monitoring elements, temporal design, and scale of analysis at South Florida/Caribbean Network parks as part of the protocol for forest vegetation monitoring.

Element	Temporal Design	Scale of Analysis
Status of cover class values of vascular species and strata	Recorded for all plots in a focal forest community type in a single sampling season, conducted once every five years.	The plot is the sampling unit. Summaries and analyses typically focus on plant guilds or focal, common species. Data for each forest community are summarized after each sampling event, once every five years. Trend analyses require at least three sampling events per plot and will be performed separately for different forest community types within each park.
Forest classification	Recorded for all plots in a focal forest community type in a single sampling season, conducted once every five years.	The plot is the sampling unit. Forest vegetation association identification, using the forest classification from the specific map product (Table 1 in SOP FVM02), is summarized after each sampling event, once every five years.
Site characteristics – Geomorphology	Recorded for all plots in a focal forest community type in a single sampling season.	The plot site is the sampling unit. Data for each forest community are summarized after the initial sampling event, at the end of the first five years.
Site characteristics – Water	Recorded for all plots in a focal forest community type in a single sampling season, conducted once every five years.	The plot site is the sampling unit. Data for each forest community are summarized after each sampling event, once every five years.

Table 8. Timeline of forest plot monitoring and reporting activities in the South Florida/Caribbean Network from 2019-2034.

Timing	Fieldwork (veg)	Reporting (Event and Status) * Completed during the Summer	Reporting (Status and Trends) * Completed during the Summer
Fall 2019 – Spring 2020	Panel 1	Panel 1	NA
Fall 2020 – Spring 2021	Panel 2	Panel 2	NA
Fall 2021 – Spring 2022	Panel 3	Panel 3	NA
Fall 2022 – Spring 2023	Panel 4	Panel 4	NA
Fall 2023 – Spring 2024	Panel 5	Panel 5	NA
Fall 2024 – Spring 2025	Panel 1	Panel 1	NA
Fall 2025 – Spring 2026	Panel 2	Panel 2	NA
Fall 2026 – Spring 2027	Panel 3	Panel 3	NA
Fall 2027 – Spring 2028	Panel 4	Panel 4	NA
Fall 2028 – Spring 2029	Panel 5	Panel 5	NA
Fall 2029 – Spring 2030	Panel 1	NA	Panel 1
Fall 2030 – Spring 2031	Panel 2	NA	Panel 2
Fall 2031 – Spring 2032	Panel 3	NA	Panel 3
Fall 2032 – Spring 2033	Panel 4	NA	Panel 4
Fall 2033 – Spring 2034	Panel 5	NA	Panel 5

Section 6. Data Management, Analysis, and Reporting

Data Management and Process Workflows

The South Florida/Caribbean Network has adopted the data processing steps and quality control procedures utilized by the CUPN Vegetation Monitoring Protocol (White et al. 2011). Where necessary, the South Florida/Caribbean Network has modified CUPN procedures and workflow specifications to maintain consistency with current I&M standards and with SFCN's approved data management plan (Witcher 2008). A full description of the SFCN's Forest Vegetation Monitoring Protocol's data management and QA/QC practices is provided in SOP FVM10 *Data Quality Assurance and Quality Control* (Patterson and Londoño 2019b) and SOP FVM11 *Data Management: Procedures upon Return from the Field* (Patterson and Londoño 2019c). The data management workflow is as follows:

Step 1—Preparation

The field crew is trained on scientific methods and on data collection and processing procedures, park logistics are planned, field supplies are assembled following equipment lists, and paper datasheets are printed (10 different sheets per plot, plus spare copies of each).

Step 2—Maps and GPS

Park maps (with color/infrared aerial backgrounds) are printed. Map images include plot locations, plot identification, UTM grids, park boundaries, and any other helpful field navigation features (e.g., roads, trails). X and Y coordinates of each plot are exported from ArcGIS into handheld GPS units.

Step 3—Data Acquisition

Field data are recorded by the field crew on paper datasheets for each plot, in accordance with all SOP instructions.

Step 4—Datasheet Review and Validation

Before leaving the plot, a member of the field crew reviews all datasheets for completeness. Datasheets are photographed (digitally scanned if possible) at the end of the field day to create a backup copy. The protocol lead or field crew leader checks each datasheet for completeness, realistic entries, the use of correct and current taxonomy for species identifications, and the correct spelling of scientific names.

Step 5—Plot Photographs and Plant Photo Vouchers

Digital images of the plot are collected by a member of the field crew and shown to a second field crew member for validation. Images are loaded onto a field computer at the end of the field day.

Step 6—Accepted Datasheets

Validated datasheets are scanned and stored on the SFCN share drive as a single file per sample event (i.e., all datasheets from a single plot and sample year, pdf format). Photographs are also stored on the SFCN server.

Step 7—Data Entry, Processing, and Backup

All entries that were recorded on the paper datasheets are entered into the forest vegetation monitoring database as soon as possible after data collection. This is completed upon return to the SFCN office or, less frequently, on a field computer while on travel. The South Florida/Caribbean Network will use a modified version of the CUPN database. The person entering data should be someone who participated in the data collection, or the project lead.

Step 8—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 data entry person compares each value in the database to each value on the paper 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, the protocol lead reviews 10% of all datasheets, again for proper entry from the datasheet. This is the 10% check, and functions as quality review. If the protocol lead is the crew member who performs the 100% check, then the data manager or other staff performs the 10% check instead of the protocol lead. The final product at this stage is verified and quality-checked data in the database.

Step 9—Database Validation

Once data are verified as entered correctly, additional validation tests are completed by the protocol lead to ensure that data in the database are logically consistent and realistic. These steps include plotting data points, calculating summary statistics, and reviewing species lists. Any problems uncovered by this process prompt the protocol lead to go back to the database records and apply appropriate quality flagging and/or documentation where applicable. At the end of this stage, the product is validated data in the database.

Step 10—Accepted Database

After both verification and validation steps are complete, the data are classified as accepted, or certified if an approved quality assurance plan is in place.

Step 11—Protected Data Agreement

An accepted or certified data set is processed to apply any record-level removal or obscuring to sensitive data, as required by park-specific data handling agreements. The output of this step is a .csv flat file. This is the version of the data made available publicly.

Step 12—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. These products should be completed within three months of the final sampling event for a given field season.

Step 13—Data Analysis and Product Development

Data are summarized, analyzed, and prepared for reports and presentations following the procedures outlined in the Data Analysis section. Forest Monitoring Event and Status Reports are created for each park during the summer following a sampling event. After the first three sampling events per

site are completed and summarized, more in-depth reports on ‘Status and Trends in Forest Vegetation’ are prepared, including results of statistical analyses of cross-year trends.

Step 14—Product Posting and Distribution

Finalized products are distributed to parks and other stakeholders, and posted to the [Integrated Resource Management Application \(IRMA\)](#) Data Store portal. 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 IRMA Data Store on an annual basis. All products posted will have the appropriate access applied.

Step 15—Protocol Operational Review

The annual operational review for the protocol addresses a variety of implementation topics, including how well the data management and QA/QC processes are working.

QA/QC

The South Florida/Caribbean Network resamples approximately 5% of sampled plots annually to determine reliability of data collection. This quality control step is also employed by the Cumberland Piedmont Network, Gulf Coast Network, and Southeast Coast Network vegetation monitoring protocols. The methods for quality control and assurance are detailed in SOP FVM10 *Data Management, Quality Assurance and Quality Control* (Patterson and Londoño 2019b).

Data Processing and Data Quality Levels

The data processing steps, their associated products, and their frequency of completion are listed in Table 9. Table 9 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.

Table 9. Data processing steps for the SFCN Forest Vegetation Monitoring Protocol (adapted from Carlson et al. 2018 and Boyle et al. 2019).

Data Type	Processing Steps	Product Name	Timing
Datasheets	1. Filled-in by hand in the field	Datasheets	At the end of each plot sampling event
	2. Reviewed for completeness	Reviewed datasheets	At the end of each plot sampling event
	3. Reviewed by the protocol lead or field lead	Reviewed datasheets	At the end of each field sampling day, or within a week
	4. Digitally scanned	Scanned datasheets	At the end of each field sampling day, or within a week
	5. Paper copies are managed as long-term records	Local file storage of reviewed datasheets	Within three months of field season's end
	6. Scanned copies are published to NPS Data Store with permissions in alignment with park protected records guidance.	Publication of scanned datasheets	Within 12 months of field season's end
Photographs	1. Photos taken in the field	Photos	At the end of each plot sampling event
	2. Images reviewed for completeness	Photos	At the end of each plot sampling event
	3. Images downloaded and renamed	Renamed and organized photos	At the end of each plot sampling event
	4. Images are archived locally	Local archives of photos	Within 6 months of field season's end
	5. Images used in 'Event and Status' reports.	Event and Status Reports	Within twelve months of field season's end
	6. Images used in 'Status and Trend' reports	Status and Trend Reports	After three data collection events for a given park
Database	1. Data manually entered	Raw data	Within several weeks of the field sampling day
	2. Verification during data entry: self-check	Raw data	Within several weeks of the field sampling day
	3. Verification after data entry: 100% check performed by someone who did not enter the data	Raw data	Within several weeks of the field sampling day
	4. Verification after data entry: Protocol lead performs a 10% check of all datasheets for a given field season	Provisional data	Within one month of field season's end
	5. Summary statistics generated to identify outliers	Provisional data	Within three months of field season's end

Table 9 (continued). Data processing steps for the SFCN Forest Vegetation Monitoring Protocol (adapted from Carlson et al. 2018 and Boyle et al. 2019).

Data Type	Processing Steps	Product Name	Timing
Database (continued)	6. Species lists are checked for unexpected records	Provisional data	Within three months of field season's end
	7. Metadata created for the dataset	Accepted (or Certified) data	Within three months of field season's end
	8. Database backends and metadata are published to NPS Data Store with permissions in alignment with park protected records guidance.	Offsite archive and publication	Within twelve months of field season's end
	9. Data are analyzed and reports generated	• Event and Status Reports • Status and Trend Reports	• Within twelve months of field season's end • After three data collection events for a given park

Data Archiving

Once digital products are created, processed and approved in the steps above, the protocol lead, in coordination with the data manager (data or photos) or managing editor (published reports), prepares them for posting to IRMA Data Store. The types of products that are posted on IRMA Data Store for this project include annual Forest Monitoring Event and Status Reports and Status and Trends in Forest Vegetation reports (after three rounds of data collection per park, and may be more frequent after the first report), digital scans of data sheets, and .csv formatted exports of annual data sets from the SFCN forest monitoring database. In their unfinished or provisional forms, these products are generally stored only on the SFCN server. The SFCN forest monitoring database will be modified from the CUPN database, which is a customized Microsoft Access relational database application used for storage and manipulation of project data. This database was developed using the Natural Resource Database Template (NRDT; NPS 2008a), but will be modified to keep up with the latest IMD database standards.

The timing of posting new products to IRMA Data Store is annually, if not more often. Products on IRMA Data Store can be shared with the public or classified as restricted access to specific individuals. Public access is given to final, approved reports or to datasets that are accepted or certified and from which protected data have been withheld, where appropriate. Restricted access on IRMA Data Store may be used for provisional products or versions of files that include protected information. All related data products beginning in 2020 are posted to the [SFCN Forest Vegetation Monitoring Project](#). Refer to the IRMA Data Store website for upload and product linking instructions, and coordinate with the SFCN data manager or managing editor when undertaking product upload steps.

When a product is posted on IRMA Data Store, the SFCN managing editor or data manager, or national publications manager creates a reference record for it that is specific to the IRMA platform.

The reference record contains citation information, relevant metadata and keywords. This is done for all products, including reports, other publications, data sets, or sets 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, if new species records were identified for parks in a season, they are entered into the NPSpecies application manually; NPSpecies is the NPS system for maintaining park-specific species lists and observation data. NPSpecies is an application within the IRMA architecture. Where many new records need to be entered for a given season, the SFCN data manager provides appropriate guidance and coordinates with NPSpecies administrators to execute a batch upload.

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 FVM15 (Whelan 2019a). 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 SFCN 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 SFCN vital signs protocol folder on the SFCN network drive and on the IRMA Data Store.

Data Analysis

After three complete sampling cycles, generalized linear mixed model analyses can be used to evaluate the data for trends. 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 (non-Normal) distributions, such as negative binomial or Poisson (for count data) or binomial (for proportions). For analyses of cover class data, ordinal logistic regression (Guisan and Harrell 2000) or an ordinal beta hurdle model (Irvine et al. 2016) may be used. Statistical analyses are performed in R (R Core Team 2019) or other statistical software, using a variety of statistical packages appropriate for the analyses. Focal variables for baseline status and trend within parks, in forest community types within parks, and in forest community types across parks 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. The South Florida/Caribbean Network also plans to utilize data collected on key stressors associated with ecosystems in the network as potential covariates during analysis. Data collected by other National Park Service and partner programs include fire history, weather and climate, visitor use/management activities, and landscape dynamics (e.g., land use change). These ancillary data may help account for variability in the relationship between certain response variables (e.g., tree growth or mortality rate) and make it easier to detect trends.

The network also plans to use multivariate approaches to further investigate vegetation community composition and changes over time using a block multi-response permutation procedure (MRPP) to test the null hypothesis of no change between survey periods in the understory vegetation plots. Tests of significance of change will be based on random permutations across years of within plot differences in species composition, calculated using a Euclidean dissimilarity measure and species presence/absence (Mielke and Berry 2001). These methods have been used successfully in the North Carolina Piedmont to investigate community changes in total and native species richness, as well as changes in herb and tree seedling composition over time in permanent fixed plots that span a range of soil and site conditions and a range of successional stage forest types (Taverna et al. 2005). Other studies using similar analytical methods (MRPP and Nonmetric Multidimensional Scaling [NMDS]) at these same sites indicated accelerated vegetation changes associated with deer herbivory between 1977 and 2010 (Israel 2011). Ordination techniques, such as NMDS, can be used to assess the magnitude and direction of vegetation compositional change visually and with respect to environmental covariates. Palmquist et al. (2015) used similar analytics to evaluate the response of vegetation to changes in disturbance regimes in fire-adapted longleaf pine habitats in the outer Coastal Plain of North Carolina. Analyses will be performed in consultation with the Southeast Region Inventory and Monitoring Division's quantitative ecologist.

Reporting

For more details on analysis and reporting, see SOP FVM12 *Data Analysis and Reporting* (Whelan 2019b).

The data collected from the SFCN forest monitoring protocol follows analysis and reporting schemes across two time intervals similar to the CUPN's Vegetation Monitoring Program:

- **Annual Event and Status Report:** data summaries on the key vegetation attributes for each focal forest community or forest of special management concern within a park, following a single sampling season in each park (i.e., produced during the summer following a sampling event).
- **Status and Trends Report:** analysis of changes (repeat measures) in key vegetation attributes over time across a focal forest community or forest of special management concern within a park, following three sampling iterations for each park. The trend reports include a condition assessment using standard symbology to depict current condition and trends for selected ecosystem parameters. The trend reports also evaluate relationships between key stressors and key measures, including comparisons to regional datasets to assess how NPS lands factor into a landscape context.

During the summer after each sampling year, data are analyzed to produce an Event and Status Report from each sampled SFCN park. This report provides park managers and partners with an updated set of data and current status relevant to policy and management decisions. All or most of the monitoring elements listed in Table 4 are summarized, including the development of an ecological integrity assessment rating for focal forest communities within each park. The South Florida/Caribbean Network also analyzes changes in these same monitoring elements to produce a

Status and Trends Report. These analyses typically take place once three sampling cycles have occurred within a park. Full descriptions of the steps in data analysis and reporting are in SOP FVM12 *Data Analysis and Reporting* (Whelan 2019b).

In addition to the two report formats, the South Florida/Caribbean Network also produces annual resource briefs of key results for each park. 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 annual basis, with the intent to provide readers a timely first look at the subject. Another type of potential 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. Production of peer-reviewed articles also legitimizes monitoring results in a way that grey literature reports cannot, and renders SFCN science more useful for science-based management actions where legal sufficiency is a prominent consideration.

Furthermore, it is the hope of the South Florida/Caribbean Network to collaborate with other NPS I&M Networks to determine appropriate regional analyses that can be conducted with the forest monitoring data from our network. Contributing towards regional analyses will provide context for conditions and trends observed in SFCN parks and strengthen our understanding of regional trends.

Section 7. Budget

The estimated annual costs for implementing the SFCN Forest Vegetation Monitoring Protocol are in FY2019 dollars (Table 10). The budget calculations use estimated sampling effort per plot and include additional data-management support costs. A hypothetical SFCN staff team (including interns) will perform all work and individual parks may provide support for monitoring, including staff participation in fieldwork, logistical support, and site access assistance. Additionally, other Inventory and Monitoring Network staff may be available for fieldwork assistance and database development. However, the budget listed in Table 10 does not include park or other partner support. It is a maximum cost estimate assuming full travel and personnel costs needed to implement the protocol. The workload estimates in Table 10 account for the first five years of plot installation, which takes more time than the resurvey events. The time estimate for data management includes pre-mission preparation, pre-sampling communication with park units, training, post mission archiving, data entry, QA/QC, and data acceptance/certification. The network will reassess the budget after the initial five-year timeframe.

Startup costs do not include a number of items already owned by the SFCN. These items include field vehicles, a marine boat, an airboat, an ATV with trailer, access to an NPS swamp buggy, access to an NPS helicopter, PPE for aforementioned equipment, computer support, radios, and safety communication gear. Items specific to this protocol are already owned by the SFCN (approximate costs): distance measuring device (\$1,000), laser range finder (\$1,000), densiometer (\$120), digital cameras (\$100 each), handheld GPS units (\$150), meter tapes (\$100), and dbh tapes (\$40).

The SFCN community ecologist is the protocol lead and provides project direction and oversight. A single team of three individuals will perform the fieldwork. The team will be comprised of some combination of the following: community ecologist, GS-7 biological technician (the field lead “botanist”), GS-7 biological technician, intern (field assistant), other NPS staff, or a NPS volunteer. Data management, including all aspects of managing data throughout its life cycle, is coordinated between the SFCN community ecologist and the data manager.

Fieldwork occurs in each of the eight fall to spring months of a five-year cycle, or implementation cycle (see Table 8). The summer of each year is utilized for data analysis and reporting (see Table 8). A total of 136 plots (plus an additional two QA/QC plots per year) are sampled across all seven SFCN parks and sample years include:

- Year 1—28 plots (plus two QA/QC plots)—Panel 1
- Year 2—25 plots (plus two QA/QC plots)—Panel 2
- Year 3—30 plots (plus two QA/QC plots)—Panel 3
- Year 4—25 plots (plus two QA/QC plots)—Panel 4
- Year 5—28 plots (plus two QA/QC plots)—Panel 5

The Cumberland Piedmont Network estimates that 2.2 vegetation plots can be completed per day in their 14 parks, utilizing a single two-person field crew (White et al. 2011), although they later

increased their crew size to three people. The Gulf Coast Network estimates 1.6 plots/day for their eight parks, while utilizing a single, three-person field crew (Carlson et al. 2018). For both the Cumberland Piedmont Network and Gulf Coast Network, this equates to a total of eight to ten plots per five-day week. The Southeast Coast Network assumes a similar rate for its set of fifteen parks; however, because the network is utilizing two field crews in its second year and beyond of protocol implementation, it estimates that a total of twelve plots per five-day week can be completed. Consistent with the Cumberland Piedmont and the Gulf Coast Networks, the South Florida/Caribbean Network estimates 1.6 plots/per day in seven parks while utilizing a three-person field crew. This equates to a total of eight plots per five-day week.

Table 10. Estimated annual operating cost (based on FY2019 dollars) for implementation of the South Florida/Caribbean Network's Forest Vegetation Monitoring Protocol.

Category	Type	Cost/Day ¹	# of days	Total Cost	Notes
Personnel	Community Ecologist (GS-12/6)	\$520	49	\$25,480	20 (startup years) / 15 (all other years) field days, 5 travel days, 14 data management days, 10 analysis and reporting days
	Field Lead Biological Technician (GS-7/6)	\$264	72	\$19,008	35 (startup years) / 30 (all other years) field days, 7 travel days, 20 data management days, 10 analysis and reporting days
	Biological Technician (GS-7/6) (split between 2 technicians)	\$304	67	\$20,368	35 (startup years) / 30 (all other years) field days , 7 travel days, 20 data management days, 5 analysis and reporting days
	Biological Technician Intern	\$120	67	\$8,040	35 (startup years) / 30 (all other years) field days, 7 travel days, 30 data management days
	Assistant Data Manager (GS9/3)	\$296	15	\$4,440	15 days data management
	SFCN Data Manager (GS-12/2)	\$360	5	\$1,800	5 days data management
	Total Personnel Costs	NA	NA	\$79,136	–
Equipment and Supplies	Field Supplies ¹	NA	NA	\$500	Field sampling and safety supplies; plant identification supplies
	Vehicle Fuel / Oil	NA	NA	\$3,000	Assumes use of existing SFCN equipment (airboat, swamp buggy, and ATVs will vary depending on year).
	Total Equipment and Supplies Costs	NA	NA	\$3,500	–
Travel	Annualized Travel Costs²	NA	NA	\$15,500	Calculated total travel for five-year panel as \$77,500 (includes air fare, and standard lodging and per diem)
Total	TOTAL ANNUAL COST	NA	NA	\$98,136	Estimated total implementation cost for startup and subsequent field-year

¹ Cost per day includes estimate for benefits based on 2019 salaries

² Estimates based on past travel expenditures. Also includes combined travel with the SET monitoring efforts at Caribbean parks.

Section 8. Safety

Implementation of the SFCN Forest Vegetation Monitoring Protocol has multiple complex risks. Both prior to and during the implementation of this protocol, involved staff must evaluate risks at the programmatic, personnel, and site level. Programmatic-scale safety information is presented here and is also detailed in SFCN SOP FVM14 *Safety* (Muxo 2019a). Procedures to mitigate risks associated with specific activities, such as vehicle use and operation (including motorized boats) are provided in Appendix B—*Field Safety*.

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 are regularly 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, and venomous and other hazardous animals.
- In specific cases, crew members travel by watercraft, swamp buggy, UTV / ATV and helicopter 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, swamp buggy, UTV / ATV and helicopter—are the most significant risks encountered when conducting this activity.

Less significant risks include heat exposure, insect bites, exposure to poisonous plants, sudden weather events, wildlife encounters, navigation error, or equipment failure.

Based on the job hazard analyses and associated risk abatement measures, it was determined that this protocol can be safely implemented provided that South Florida/Caribbean Network 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 includes certification in basic first aid. To increase the overall level of safety and awareness, obtaining additional levels of training beyond basic certification 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, SFCN staff members follow the general

guidelines set forth in the NPS Occupational Safety and Health Program Reference Manual (Directors Order #50B; NPS 2008b).

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 CUPN SOPs, as well as one GULN SOP. Two SOPs have been adopted from the SFCN Periphyton Protocol, one SOP was created but was conceptually based on the CUPN protocol (sample design), and one SOP was created to give instructions on a particular piece of equipment used to measure distance (see Table 11). All approved versions of operational SOPs are available for download from the [IRMA Data Store Portal](#).

Table 11. Standard Operating Procedures required to implement the SFCN Forest Vegetation Monitoring Protocol in SFCN parks. The table includes a brief description of changes from the source document to the SFCN version. Additional details on these changes are provided at the start of each SFCN SOP.

Topic	Source Protocol or SOP	Explanation of Differences	SFCN Updated SOP	IRMA Record
Preparation for the Field Season	CUPN SOP 1: Field Season Preparation	Changes were made to the SOP to reflect the use of a single field crew. Other minor editorial changes to equipment list were also made.	Shamblin, R.B. 2019a. Field Season Preparation—Version 1.0. South Florida/Caribbean Network Standard Operating Procedure NPS/SFCN/SOP—FVM01. South Florida/Caribbean Network, Palmetto Bay, Florida.	2267809
GPS Use	CUPN SOP 2: Using GPS	Converted SOP to give instructions for the GPS equipment that the SFCN uses.	Muxo, R. 2019b. Using GPS (Based on use of the Garmin GPSMAP 60CSx and newer GPS units)—Version 1.0. South Florida/Caribbean Network Standard Operating Procedure NPS/SFCN/SOP—FVM09. South Florida/Caribbean Network, Palmetto Bay, Florida.	2267809
Sample Design	CUPN Protocol Sample Design	Two specific modifications: (1) parks were stratified into focal forest communities, and (2) those focal forest polygons had road, trail, building, park inholding, steep (>30 degree) slope, habitat edge, and park boundary buffers applied to create a sampling frame that was used for the GRTS draw.	Patterson, J. M., and M. Londoño. 2019a. Sampling Design and In Office Review —Version 1.0. South Florida/Caribbean Network Standard Operating Procedure NPS/SFCN/SOP—FVM02. South Florida/Caribbean Network, Palmetto Bay, Florida.	2267809

Table 11 (continued). Standard Operating Procedures required to implement the SFCN Forest Vegetation Monitoring Protocol in SFCN parks. The table includes a brief description of changes from the source document to the SFCN version. Additional details on these changes are provided at the start of each SFCN SOP.

Topic	Source Protocol or SOP	Explanation of Differences	SFCN Updated SOP	IRMA Record
In field Site Selection and Establishment; Site Classification	CUPN SOP 3: Site Selection and Plot Establishment and CUPN SOP 9: U.S. National Vegetation Classification Measure	Six specific modifications: (1) Plot classification occurs using information from the specific map products following the steps from CUPN SOP9 but using definitions from map products; (2) forest plot sizes and shapes cannot be modified; (3) plots are established initially by using a GPS and pacing procedure outlined by the Northeast Temperate Network (NETN; Tierney et al. 2016); (4) SFCN plots can be shifted up to 10 meters if any portion of the plots occurs within a restricted category, rather than if more than ¼ of the plot occurs in a restricted category in the CUPN; (5) additional information on site hydrology similar to what is defined in the Gulf Coast Network vegetation monitoring effort (Carlson et al. 2018) was added; (6) areal cover percentages are estimated for each disturbance indicator located within a SFCN forest plot.	Shamblin, R.B. 2019b. Plot Evaluation, Plot Establishment, and Return Visits—Version 1.0. South Florida/Caribbean Network Standard Operating Procedure NPS/SFCN/SOP—FVM03. South Florida/Caribbean Network, Palmetto Bay, Florida.	2267809
Photo points	CUPN SOP 4: Plot Photo Points	A section was added to account for a panoramic photo taken at plot center.	Shamblin, R.B. 2019c. Plot photo points—Version 2.0. South Florida/Caribbean Network Standard Operating Procedure NPS/SFCN/SOP FVM04-Plot Photo Points. South Florida/Caribbean Network, Palmetto Bay, Florida.	2267809

Table 11 (continued). Standard Operating Procedures required to implement the SFCN Forest Vegetation Monitoring Protocol in SFCN parks. The table includes a brief description of changes from the source document to the SFCN version. Additional details on these changes are provided at the start of each SFCN SOP.

Topic	Source Protocol or SOP	Explanation of Differences	SFCN Updated SOP	IRMA Record
Canopy Closure and Stand Height Measurements	CUPN SOP 5: Canopy Closure and Stand Height Measurements	Minor editorial modifications and updating to reflect SFCN equipment.	Shamblin, R.B. 2019d. Canopy Closure and Stand Height Measurements—Version 1.0. South Florida/Caribbean Network Standard Operating Procedure NPS/SFCN/SOP—FVM05. South Florida/Caribbean Network, Palmetto Bay, Florida.	2267809
Tree Measurements	CUPN SOP 6: Tree Measurements	Five specific modifications: (1) combining trees and large lianas (dbh ≥5cm) into a single woody stem category; (2) damage codes for woody stems were updated for South Florida vegetation issues (3) changing the DBH cutoff from greater than or equal to 10 cm to greater than or equal to 5 cm, (4) DBH measurements are rounded off to 0.1 cm not to 1.0 cm, and (5) using bearing and distance to generate tree map.	Shamblin, R.B. 2019e. Tree measurements—Version 1.0. South Florida/Caribbean Network Standard Operating Procedure NPS/SFCN/SOP—FVM06. South Florida/Caribbean Network, Palmetto Bay, Florida.	2267809
Diversity and Seedling/Sapling Density, Species Nomenclature	CUPN SOP 7: Herbaceous Plant and Seedling/Sapling Measurements and CUPN SOP 14 Recording Species Nomenclature and Data Field Descriptions	There are seven specific modifications: (1) combination of the two CUPN SOPs into one, (2) Changed taxonomic authority, (3) inclusion of shrub and woody vines (lianas) in the seedling/sapling measurements, (4) assignment of cover class values at the modular level rather than the plot level, (5) no collection of voucher specimens, (6) use of two observers to determine cover class values, (7) Sapling size class stops at 5 cm dbh.	Shamblin, R.B. 2019f. Species diversity and Seedling/Sapling Measurements—Version 1.0. South Florida/Caribbean Network Standard Operating Procedure NPS/SFCN/SOP—FVM7. South Florida/Caribbean Network, Palmetto Bay, Florida.	2267809

Table 11 (continued). Standard Operating Procedures required to implement the SFCN Forest Vegetation Monitoring Protocol in SFCN parks. The table includes a brief description of changes from the source document to the SFCN version. Additional details on these changes are provided at the start of each SFCN SOP.

Topic	Source Protocol or SOP	Explanation of Differences	SFCN Updated SOP	IRMA Record
Woody Debris	CUPN SOP 8: Coarse Woody Debris	Two specific modifications: (1) there are three 25-meter (82-ft) fuel transects used and they are arrayed similar to the CWD design in the Northeast Temperate Network's forest monitoring protocol (Tierney et al. 2016); and (2) the SFCN includes Fine Woody Debris, Duff, and Litter as described in the FIREMON protocol (Lutes et al. 2006).	Prats, M.C. 2019a. Woody Debris—Version 1.0. South Florida/Caribbean Network Standard Operating Procedure NPS/SFCN/SOP—FVM08. South Florida/Caribbean Network, Palmetto Bay, Florida.	2267809
Soils	CUPN SOP 10: Soil Measurements	No soil samples are taken	—	—
QA/QC	CUPN SOP 11: Data Quality Assurance and Quality Control and SECN SOP 2.4.05	Two specific modifications: (1) Minor editorial changes were made, and (2) Followed SECN example for QA/QC plot sampling.	Patterson, J.M. and M. Londoño. 2019b. Data Quality Assurance and Quality Control—Version 1.0. South Florida/Caribbean Network Standard Operating Procedure NPS/SFCN/SOP—FVM10. South Florida/Caribbean Network, Palmetto Bay, Florida.	2267809
Data Management	CUPN SOP 12: Data Management: Procedures upon Return from the Field	Two specific modifications: (1) Minor editorial changes were made, (2) Refraining from collecting physical voucher specimens and using photographs instead.	Patterson, J.M. and M. Londoño. 2019c. Data Management: Procedures upon Return from the Field—Version 1.0. South Florida/Caribbean Network Standard Operating Procedure NPS/SFCN/SOP—FVM11. South Florida/Caribbean Network, Palmetto Bay, Florida.	2267809
Analysis and Reporting	GULN SOP VEG10: Data Analysis and Reporting	Included a section on multivariate analysis techniques.	Whelan, K. R. T. 2019b. Data analysis and reporting—Version 1.0. South Florida/Caribbean Network Standard Operating Procedure NPS/SFCN/SOP—FVM12 South Florida/Caribbean Network, Palmetto Bay, Florida.	2267809

Table 11 (continued). Standard Operating Procedures required to implement the SFCN Forest Vegetation Monitoring Protocol in SFCN parks. The table includes a brief description of changes from the source document to the SFCN version. Additional details on these changes are provided at the start of each SFCN SOP.

Topic	Source Protocol or SOP	Explanation of Differences	SFCN Updated SOP	IRMA Record
Deviations and Summary of Major Changes	CUPN SOP 15: Deviations and Summary of Major Changes	Minor editorial changes to make it SFCN specific.	Prats, M.C. 2019b. Deviations and Summary of Major Changes—Version 1.0. South Florida/Caribbean Network Standard Operating Procedure NPS/SFCN/SOP—FVM13. South Florida/ Caribbean Network, Palmetto Bay, Florida.	2267809
Map tree locations	New SOP for specific equipment used by SFCN	This SOP covers the instructions for the use of the distance ranger finder piece of equipment used by the SFCN.	Shamblin, R.B. 2019. Using Haglöf DME Distance Ranger Finder—Version 1.0. South Florida/Caribbean Network Standard Operating Procedure NPS/SFCN/SOP—FVM16. South Florida/Caribbean Network, Palmetto Bay, Florida.	2267809
Safety	SFCN Periphyton Monitoring in Big Cypress National Preserve: Protocol narrative. Safety section	Minor editorial changes to specify the instructions for this PIP.	Muxo, R. 2019a. Safety—Version 1.0. South Florida/Caribbean Network Standard Operating Procedure NPS/SFCN/SOP—FVM14. South Florida/Caribbean Network, Palmetto Bay, Florida.	2267809
Revisions	SFCN Periphyton Monitoring in Big Cypress National Preserve: Protocol narrative. SFCN SOP 12: Revising the protocol	Minor editorial changes to specify the instructions for this PIP.	Whelan, K. R. T. 2019a. Revising the Protocol—Version 1.0. South Florida/Caribbean Network Standard Operating Procedure NPS/SFCN/SOP—FVM15. South Florida/Caribbean Network, Palmetto Bay, Florida.	2267809

Literature Cited

- Acevedo-Rodriguez, P. 1996. *Flora of St. John*, 2nd printing. New York Botanical Garden Press, Bronx, New York.
- Areces-Mallea, A. E., A.S. Weakley, X. Li, R.G. Sayre, J.D. Parrish, C.V. Tipton, and T. Boucher. 1999. *A Guide to Caribbean Vegetation Types: Preliminary Classification System and Descriptions*. The Nature Conservancy.
- Bennett, B. 1995. *Vegetation studies in hammock communities and revegetated sites in Biscayne National Park*, Research Proposal.
- Boyle, M. F., M. B. Gregory, M. W. Byrne, P. Capece, and S. Corbett. 2019. *Terrestrial vegetation monitoring in Southeast Coast Network parks: Protocol implementation plan*. Natural Resource Report NPS/SECN/NRR—2019/1930. National Park Service, Fort Collins, Colorado. Available at: <https://irma.nps.gov/DataStore/Reference/Profile/2263392> (last accessed December 2019).
- Carlson, J. E., J. Bracewell, W. Granger, and M. Segura. 2018. *Monitoring vegetation in Gulf Coast Network parks: Protocol implementation plan*. Natural Resource Report NPS/GULN/NRR—2018/1746. National Park Service, Fort Collins, Colorado. Available at: <https://irma.nps.gov/DataStore/Reference/Profile/2256507> (last accessed December 2019).
- Desantis, L. R., S. Bhotika, K. Williams, and F. E. Putz. 2007. Sea-level rise and drought interactions accelerate forest decline on the Gulf Coast of Florida, USA. *Global Change Biology*, 3(11): 2349–2360.
- DeVivo, J. C., C. J. Wright, M. W. Byrne, E. DiDonato, and T. Curtis. 2008. *Vital signs monitoring in the Southeast Coast Inventory and Monitoring Network*. Natural Resource Report NPS/SECN/NRR—2008/061. National Park Service, Fort Collins, Colorado. Available at: <https://irma.nps.gov/DataStore/Reference/Profile/660552> (last accessed December 2019).
- DeVivo, J. C., L. Nelson, M. Kineth, T. Philippi, and W. B. Monahan. 2018. *Protocol for monitoring environmental setting for National Park Service units: Landscape dynamics, climate, and hydrology*. Natural Resource Report NPS/IMD/NRR—2018/1844. National Park Service, Fort Collins, Colorado. Available at: <https://irma.nps.gov/DataStore/Reference/Profile/2258457> (last accessed December 2019).
- Duever, M.J., J.E. Carlson, J.F. Meeder, L.C. Duever, L.H. Gunderson, L.A. Riopelle, T.R. Alexander, R.L. Myers, and D.P. Spangler. 1979. *The Big Cypress National Preserve*. National Audubon Society. New York, New York.
- Eggers, H. F. A. 1879. *The flora of St. Croix and the Virgin Islands*. *Bulletin of the United States National Museum*. 1–133.

- Faber-Langendoen, D., J. Rocchio, M. Schafale, C. Nordman, M. Pyne, J. Teague, T. Foti, and P. Comer. 2006. Ecological integrity assessment and performance measures for wetland mitigation. NatureServe, Arlington, Virginia.
- Fancy, S. G., J. E. Gross, and S. L. Carter. 2009. Monitoring the condition of natural resources in US National Parks. *Environmental Monitoring and Assessment* 151:161–174. Available at <https://irma.nps.gov/DataStore/Reference/Profile/2124308> (last accessed December 2019).
- Federal Geographic Data Committee (FGDC). 2008. National vegetation classification standard, version 2: vegetation subcommittee, Federal Geographic Data Committee. FGDC-STD-005-2008 (Version 2).
- Guisan, A., and F. E. Harrell. 2000. Ordinal response regression models in ecology. *Journal of Vegetation Science* 11(5):617–626.
- Gunderson, L.H. 1994. Vegetation of the Everglades: Determinants of Community Composition. In S. M. Davis, and J. C. Ogden, editors. *Everglades: The ecosystem and its restoration*. St. Lucie Press, Boca Raton, Florida.
- Irvine, K. M., T. J. Roadhouse, and I. N. Keren. 2016. Extending ordinal regression with a latent zero-augmented beta distribution. *Journal of Agricultural, Biological and Environmental Statistics* 21(4):619–640.
- Israel, K. A., 2011. Vegetation change in the Duke Forest, 1977–2010. Thesis submitted to the faculty of the University of North Carolina at Chapel Hill. Chapel Hill, North Carolina. 110 pp.
- Kincaid, T. M., and A. R. Olsen. 2017. spsurvey: Spatial survey design and analysis. R package version 3.4. Available at: <https://cran.r-project.org/web/packages/spsurvey/index.html> (last accessed March 2019).
- Lee, M. T., R. K. Peet, S. D. Roberts, and T. R. Wentworth. 2008. CVS-EEP protocol for recording vegetation, all levels of plot sampling, version 4.2. Carolina Vegetation Survey. Available at: <http://cvs.bio.unc.edu/protocol/cvs-EEP-protocol-v4.2-lev1-5.pdf> (last accessed February 2019).
- Leibfreid T. R., R. L. Woodman, and S. C. Thomas. 2005. Vital signs monitoring plan for the Cumberland Piedmont Network and Mammoth Cave National Park prototype monitoring program: July 2005. National Park Service, Mammoth Cave, Kentucky.
- Luciani, J. M., K. R. T. Whelan, R. B. Shamblin, R. M. Vargas, J. M. Patterson. 2011. Dry Tortugas National Park vegetation map, 2009. Natural Resource Technical Report NPS/SFCN/NRTR-2011/469. Available at: <https://irma.nps.gov/DataStore/Reference/Profile/2180962> (last accessed December 2019).

- Lutes, D. C., R. E. Keane, J. F. Caratti, C. H. Key, N. C. Benson, S. Sutherland, and L. J. Gangi. 2006. FIREMON: fire effects monitoring and inventory system. Gen. Tech. Rep. RMRS-GTR-164-CD. Fort Collins, Colorado. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.
- McDonald, T. L. 2004. GRTS for the Average Joe: A GRTS sampler for Windows. Available at: http://www.west-inc.com/biometrics_reports.php (last accessed February 2019).
- Mielke, P. W. Jr, and K. J. Berry. 2001. Permutation methods: A distance function approach. Springer Series in Statistics. Springer.
- Moser, J. G., K. R. T. Whelan, R. B. Shamblin, A. J. Atkinson, J. M. Patterson. 2010. Buck Island Reef National Monument, U.S. Virgin Islands, vegetation mapping project, 2009. Natural Resource Technical Report. NPS/SFCN/NRTR—2010/293. Available at <https://irma.nps.gov/DataStore/Reference/Profile/2233250> (last accessed December 2019).
- Moser, J. G., K. R. T. Whelan, R. B. Shamblin, A. J. Atkinson, and J. M. Patterson. 2011. Salt River Bay National Historical Park & Ecological Preserve, U.S. Virgin Islands, Vegetation Mapping Project, 2009. Natural Resource Technical Report. NPS/SFCN/NRTR-2011/448. Available at <https://irma.nps.gov/DataStore/Reference/Profile/2164863> (last accessed December 2019).
- Moser, J., R. B. Shamblin, T. A. Fotinos, A. J. Atkinson, J. L. Chandler, M. Londoño, J. M. Patterson, and K. R. T. Whelan. 2019. South Florida/Caribbean Network mangrove-marsh ecotone monitoring: Protocol narrative. Natural Resource Report NPS/SFCN/NRR—2019/1923. National Park Service, Fort Collins, Colorado. Available at <https://irma.nps.gov/DataStore/Reference/Profile/2260295> (last accessed December 2019).
- Muxo, R. 2019a. Safety—Version 1.0. South Florida/Caribbean Network Standard Operating Procedure NPS/SFCN/SOP—FVM14. South Florida/Caribbean Network, Palmetto Bay, Florida. Available at: <https://irma.nps.gov/DataStore/Reference/Profile/2267809> (last accessed December 2019).
- Muxo, R. 2019b. Using GPS (Based on use of the Garmin GPSMAP 60CSx and newer GPS units)—Version 1.0. South Florida/Caribbean Network Standard Operating Procedure NPS/SFCN/SOP—FVM09. South Florida/Caribbean Network, Palmetto Bay, Florida. Available at: <https://irma.nps.gov/DataStore/Reference/Profile/2267809> (last accessed December 2019).
- National Oceanic and Atmospheric Administration (NOAA). 2014. Storm events database, Version 3.0, May 12, 2014. National Centers for Environmental Information. Available at: <https://www.ncdc.noaa.gov/stormevents/> (last accessed April 2019).
- National Oceanic and Atmospheric Administration (NOAA). 2018. Tides and currents map database. Center for Operational Oceanographic Products and Services. Available at: <https://tidesandcurrents.noaa.gov/> (last accessed April 2019).

- National Park Service (NPS). 2007. Natural resource database template version 3.2 documentation. Natural Resource Program Center, Office of Inventory, Monitoring, and Evaluation, Fort Collins, Colorado. 201 pp.
- National Park Service (NPS). 2008a. Data management guidelines for inventory and monitoring networks. Natural Resource Report NPS/NRPC/NRR—2008/035. National Park Service, Fort Collins, Colorado. Available at: <https://irma.nps.gov/DataStore/Reference/Profile/653227> (last accessed December 2019).
- National Park Service (NPS). 2008b. National Park Service occupational health and safety program reference manual 50B. Available at <https://www.nps.gov/policy/RM50Bdoclist.htm> (last accessed February 2019).
- National Park Service (NPS). 2016. NPSpecies: information on species in National Parks. Available at: <https://irma.nps.gov/NPSpecies/> (last accessed July 2019).
- Oberbauer, S. F., K. von Kleist, K. R. T. Whelan, and S. Koptur. 1996. Effects of Hurricane Andrew on epiphyte communities within cypress domes of Everglades National Park. *Ecology* 77(3):964–967.
- Palmquist, K. A., R. K. Peet, and S. R. Mitchell. 2015. Scale-dependent responses of longleaf pine vegetation to fire frequency and environmental context across two decades. *Journal of Ecology* 103(4) 998–1008.
- Patterson, J. M., and M. Londoño. 2019a. Sampling design and in office review—Version 1.0. South Florida/Caribbean Network Standard Operating Procedure NPS/SFCN/SOP—FVM02. South Florida/Caribbean Network, Palmetto Bay, Florida. Available at: <https://irma.nps.gov/DataStore/Reference/Profile/2267809> (last accessed December 2019)
- Patterson, J.M. and M. Londoño. 2019b. Data quality assurance and quality control—Version 1.0. South Florida/Caribbean Network Standard Operating Procedure NPS/SFCN/SOP—FVM10. South Florida/Caribbean Network, Palmetto Bay, Florida. Available at: <https://irma.nps.gov/DataStore/Reference/Profile/2267809> (last accessed December 2019).
- Patterson, J.M. and M. Londoño. 2019c. Data management: procedures upon return from the field — Version 1.0. South Florida/Caribbean Network Standard Operating Procedure NPS/SFCN/SOP—FVM11. South Florida/Caribbean Network, Palmetto Bay, Florida. Available at: <https://irma.nps.gov/DataStore/Reference/Profile/2267809> (last accessed December 2019).
- Patterson, M.E., A.J. Atkinson, B.D. Witcher, K.R.T. Whelan, W.J. Miller, R.J. Waara, J.M. Patterson, B.I. Ruttenberg, A.D. Davis, R. Urgelles, R.B. Shamblin. 2008. South Florida/Caribbean Network vital sign monitoring plan. Natural Resource Report NPS/SFCN/NRR—2008/063. National Park Service, Fort Collins, Colorado.

- Peet, R. K., T. R. Wentworth, and P. S. White. 1998. The North Carolina Vegetation Survey protocol: a flexible, multipurpose method for recording vegetation composition and structure. *Castanea* 63:262–274.
- Perles, S. J., G. S. Podniesinski, E. Eastman, L. A. Sneddon, and S. C. Gawler. 2007. Classification and mapping of vegetation and fire fuel models at Delaware Water Gap National Recreation Area: Volume 1 of 2. Technical Report NPS/NER/NRTR—2007/076. National Park Service. Philadelphia, Pennsylvania. Available at: https://www1.usgs.gov/vip/dewa/dewaappend_g.pdf (last accessed May 2019).
- Prats, M. C. 2019a. Woody debris—Version 1.0. South Florida/Caribbean Network Standard Operating Procedure NPS/SFCN/SOP—FVM08. South Florida/ Caribbean Network, Palmetto Bay, Florida. Available at: <https://irma.nps.gov/DataStore/Reference/Profile/2267809> (last accessed December 2019).
- Prats, M. C. 2019b. Deviations and summary of major changes—Version 1.0. South Florida/Caribbean Network Standard Operating Procedure NPS/SFCN/SOP—FVM13. South Florida/ Caribbean Network, Palmetto Bay, Florida. Available at: <https://irma.nps.gov/DataStore/Reference/Profile/2267809> (last accessed December 2019).
- R Core Team. 2019. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. Available at: <http://www.R-project.org/> (last accessed March 2019).
- Ruiz, P. L., H. C. Giannini, M. C. Prats, C. P. Perry, M. A. Foguer, A. Arteaga Garcia, R. B. Shamblin, K. R. T. Whelan, and M. Hernandez. 2017. The Everglades National Park and Big Cypress National Preserve Vegetation mapping project: Interim report—Southeast Saline Everglades (Region 2), Everglades National Park. Natural Resource Report NPS/SFCN/NRR—2017/1494. National Park Service, Fort Collins, Colorado. Available at <https://irma.nps.gov/DataStore/Reference/Profile/2243281> (last accessed December 2019).
- Ruiz, P. L., C. P. Perry, A. Arteaga Garcia, M. Guichardot, M. Foguer, J. Ingram, M. C. Prats, C. Pulido, R. B. Shamblin, and K. R. T. Whelan. 2020. The Everglades National Park and Big Cypress National Preserve vegetation mapping project: Interim report—Northwest Coastal Everglades (Region 4), Everglades National Park. Natural Resource Report NPS/SFCN/NRR—2020/XXXX. National Park Service, Fort Collins, Colorado. (In Draft)
- Ruiz, P. L., A. Lee, C. Thompson, I. Castillo, M. Guichardot, C. P. Perry, A. Arteaga Garcia, M. Foguer, M. C. Prats, E. Garcia, S. Lamosa, R. B. Shamblin, and K. R. T. Whelan. 2019. The Everglades National Park and Big Cypress National Preserve vegetation mapping project: Interim report—Eastern Big Cypress (Regions 5 & 6), Big Cypress National Preserve. Natural Resource Report NPS/SFCN/NRR—2019/2035. National Park Service, Fort Collins, Colorado. Available at <https://irma.nps.gov/DataStore/Reference/Profile/2196852> (last accessed December 2019).

- Rutchev, K., T. N. Schall, R. F. Doren, A. Atkinson, M. S. Ross, D. T. Jones, M. Madden, L. Vilchek, K. A. Bradley, J. R. Snyder, J. N. Burch, T. Pernas, B. Witcher, M. Pyne, R. White, T. J. Smith III, J. Sadle, C. S. Smith, M. E. Patterson, and G. D. Gann. 2006. Vegetation classification for South Florida natural areas. Saint Petersburg, Florida, United States Geological Survey, Open-File Report 2006–1240.
- Sanders, S., S. E. Johnson, and D. M. Waller. 2006. General vegetation monitoring protocol for the Great Lakes Network, Version 1.0. National Park Service, Great Lakes Network, Ashland, Wisconsin.
- Schall, T. N., et al. 20XX. The Everglades National Park and Big Cypress National Preserve Vegetation Mapping Project: Interim report—Shark River Slough/Long Pine Key (Region 1). U.S. Army Corps of Engineers, Jacksonville, Florida. (In Draft).
- Segura, M., R. Woodman, J. Meiman, W. Granger, and J. Bracewell. 2007. Gulf Coast Network vital signs monitoring plan. Natural Resource Report NPS/GULN/NRR—2007/015. National Park Service, Fort Collins, Colorado. Available at: <https://irma.nps.gov/DataStore/Reference/Profile/661666> (last accessed February 2019).
- Shamblin, R.B. 2019a. Field season preparation—Version 1.0. South Florida/Caribbean Network Standard Operating Procedure NPS/SFCN/SOP—FVM01. South Florida/Caribbean Network, Palmetto Bay, Florida. Available at: <https://irma.nps.gov/DataStore/Reference/Profile/2267809> (last accessed December 2019).
- Shamblin, R.B. 2019b. Plot evaluation, plot establishment, and return visits—Version 1.0. South Florida/Caribbean Network Standard Operating Procedure NPS/SFCN/SOP—FVM03. South Florida/Caribbean Network, Palmetto Bay, Florida. Available at: <https://irma.nps.gov/DataStore/Reference/Profile/2267809> (last accessed December 2019).
- Shamblin, R.B. 2019c. Plot photo points—Version 2.0. South Florida/Caribbean Network Standard Operating Procedure NPS/SFCN/SOP—FVM04. South Florida/Caribbean Network, Palmetto Bay, Florida. Available at: <https://irma.nps.gov/DataStore/Reference/Profile/2267809> (last accessed December 2019).
- Shamblin, R.B. 2019d. Canopy closure and stand height measurements—Version 1.0. South Florida/Caribbean Network Standard Operating Procedure NPS/SFCN/SOP—FVM05. South Florida/Caribbean Network, Palmetto Bay, Florida. Available at: <https://irma.nps.gov/DataStore/Reference/Profile/2267809> (last accessed December 2019).
- Shamblin, R.B. 2019e. Tree measurements—Version 1.0. South Florida/Caribbean Network Standard Operating Procedure NPS/SFCN/SOP—FVM06. South Florida/Caribbean Network, Palmetto Bay, Florida. Available at: <https://irma.nps.gov/DataStore/Reference/Profile/2267809> (last accessed December 2019).

- Shamblin, R.B. 2019f. Species diversity and seedling/sapling measurements—Version 1.0. South Florida/Caribbean Network Standard Operating Procedure NPS/SFCN/SOP—FVM07. South Florida/Caribbean Network, Palmetto Bay, Florida. Available at: <https://irma.nps.gov/DataStore/Reference/Profile/2267809> (last accessed December 2019).
- Smith, T.J., III, M. B. Robblee, H. R. Wanless, and T. W. Doyle. 1994, Mangroves, hurricanes, and lightning strikes: *Bioscience*, v. 44, p. 256–263.
- Stevens, D. L., and A. N. Olsen. 2004. Spatially balanced sampling of natural resources. *Journal of American Statistical Association* 99(465):262–278.
- Snyder, J. R., A. Herndon, and W.B. Robertson, Jr. 1990. South Florida Rockland *In* “Ecosystems of Florida” (R.L. Myers and J.J. Ewell eds). University of Central Florida Press, Orlando, Florida.
- Taverna, K., R. K. Peet, and L. C. Phillips. 2005. Long-term change in ground-layer vegetation of deciduous forest of the North Carolina Piedmont, USA. *Journal of Ecology* 93:202–213.
- Thanawastien, T., H. C. Giannini, J. M. Patterson, R. B. Shamblin, and K. R. T. Whelan. 2019. The National Park Service vegetation map of Virgin Islands National Park, St. John, USVI. Draft Natural Resource Technical Report.
- Thomas, T., and B. Devine. 2005. Island peak to coral reef, a field guide to the plant and marine communities of the Virgin Islands. University of the Virgin Islands.
- Tierney, G., B. Mitchell, K. Miller, J. Comiskey, A. Kozlowski, and D. Faber-Langendoen. 2016. Northeast Temperate Network long-term forest monitoring protocol: 2016 revision. Natural Resource Report NPS/NETN/NRR—2016/1184. National Park Service. Fort Collins, Colorado.
- U.S. Department of Agriculture (USDA) Forest Service. 1999. A strategic plan for forest inventory and monitoring. Washington, District of Columbia.
- Whelan, K. R. T., P. L. Ruiz, R. B. Shamblin, P. A. Houle, M. S. Ross, A. J. Atkinson, J. M. Patterson, J. Alonso. 2013. Biscayne National Park vegetation map project. Natural Resource Technical Report. NPS/SFCN/NRTR—2013/774. Available at: <https://irma.nps.gov/DataStore/Reference/Profile/2196852> (last accessed December 2019).
- Whelan, K. R. T. 2019a. Revising the Protocol—Version 1.0. South Florida/Caribbean Network Standard Operating Procedure NPS/SFCN/SOP—FVM15. South Florida/Caribbean Network, Palmetto Bay, Florida. Available at: <https://irma.nps.gov/DataStore/Reference/Profile/2267809> (last accessed December 2019).
- Whelan, K. R. T., 2019b. Data analysis and reporting—Version 1.0. South Florida/Caribbean Network Standard Operating Procedure NPS/SFCN/SOP—FVM12 South Florida/Caribbean Network, Palmetto Bay, Florida. Available at: <https://irma.nps.gov/DataStore/Reference/Profile/2267809> (last accessed December 2019).

Whelan, K.R.T., M. Prats, A.J. Atkinson, Avineon Inc., and the Institute for Regional Conservation. 20XX. Western Big Cypress National Preserve Vegetation Map. Draft Natural Resource Technical Report.

White, R., C. Nordman, L. Smart, T. Leibfreid, B. Moore, R. Smyth, and T. Govus. 2011. Vegetation monitoring protocol for the Cumberland Piedmont Network, Version 1. Natural Resource Report NPS/CUPN/NRR—2011/XXX. National Park Service. Fort Collins, Colorado.

White, R., C. Nordman, L. Smart, T. Leibfreid, B. Moore, R. Smyth, and T. Govus. Draft (March 2017). Forest vegetation monitoring protocol for the Cumberland Piedmont Network, Version 2. Natural Resource Report NPS/CUPN/NRR—2011/XXX. National Park Service. Fort Collins, Colorado.

Witcher, B. 2008. South Florida/Caribbean Network: Data management plan. Natural Resource Report NPS/SFCN/NRR—2008/064. National Park Service, Fort Collins, Colorado. Available at: <https://irma.nps.gov/DataStore/Reference/Profile/661961> (last accessed December 2019).

Appendix A: Modifications to the Cumberland Piedmont Network Protocol and Justification for Changes

Summary

The South Florida/Caribbean Network (SFCN) has adopted the Cumberland Piedmont Network's (CUPN's) vegetation monitoring protocol (White et al. 2011) as the basis for its own forest vegetation monitoring protocol implementation plan (Whelan et al. 2019). To accommodate the diverse and varied forest vegetation communities, the extensive size and challenging terrain of some of the park units (BICY and EVER), and costly travel (airfare and high lodging costs for VIIS and SARI) of the South Florida/Caribbean Network, some substantial modifications were necessary. The bulk of these modifications were related to differing sampling needs based on the forest community types in SFCN parks, and absence of ecological integrity measures in these same parks. Modifications were also related to down-stream procedural modifications following a few key changes.

This supplemental document lists and describes the major modifications that the SFCN made to the CUPN protocol. Many of these are also elaborated upon in the relevant standard operating procedure (SOP) documents.

Major Modifications

Spatial Sampling Frame

The sampling frame used by the Cumberland Piedmont Network is forest and woodland communities within each park, and all such areas within whole parks are included. The South Florida/Caribbean Network, in contrast, includes in its sampling frame focal forest communities of interest in each park unit. Focal forests are typically the dominant forest communities in the park unit. Some additional communities of special management concern are monitored with one or two index sites per community.

To reduce the effects of human disturbance, the Southeast Coast Network specifically excludes a 14-meter buffer along park boundaries, roadways, and buildings, as well as between mapped focal forest communities. As a result, roadside and infrastructure edge habitats are not included in any park-wide or unit-wide inferences (for a similar approach, see the integrated upland monitoring protocol for the Southern Colorado Plateau Network; DeCoster et al. 2012). The South Florida/Caribbean Network also uses buffers, which we extended to 15 meters from roads, trails, buildings and park boundaries to ensure that no part of the potential forest plots would land in restricted areas. Another change was that SFCN did not apply an internal buffer between mapped focal forest communities. Some parks like Everglades NP have 50×50 meter polygons that would be dramatically reduced in size by a 15-meter internal buffer. Similarly, Virgin Islands NP and Salt River Bay NHP&EP include many small or linear polygons that would have been substantially reduced by such a buffer. By leaving these polygons unbuffered there should be situations where the field crew can move the plot up to 10 meters (32.8 ft) and ensure they fit in small polygons. Given these considerations in several parks the decision was made to keep buffering as consistent as possible and drop the habitat edge buffer entirely.

Sampling frames and spatial arrangements of plots were developed by the South Florida/Caribbean Network to fit park-specific needs and constraints. Proposed plot locations for forest vegetation monitoring in the first three SFCN parks to be monitored are presented in SOP FVM02—*Sampling Design and In Office Review* (Patterson and Londoño 2019). The rest of the proposed plot locations for SFCN parks will be identified in the near future and included in a revised SOP FVM02.

Focal Forest Stratification

The Cumberland Piedmont Network does not stratify parks into focal forest types to determine plot locations and sample size. The South Florida/Caribbean Network uses focal forest community polygons to pre-stratify the location of forest vegetation plots, and uses their relative size to determine the number of plots within each focal forest community. Focal forests are typically the dominant forest community in the park unit. Additionally, there are index plots in forest communities of special management concern. Sampling frames and spatial arrangements of plots were developed by the South Florida/Caribbean Network to fit park-specific needs and constraints. Proposed plot locations for vegetation monitoring in SFCN parks are presented in SOP FVM02—*Sampling Design and In Office Review* (Patterson and Londoño 2019).

Timing of Monitoring Effort

The Cumberland Piedmont Network initially proposed a two- and four-year sampling rotation for small and large parks, respectively, where eight plots are measured in each park in each year. This approach was later modified by the Cumberland Piedmont Network (prior to year three field season), but the initial approach is still discernable in CUPN's annual sampling panels (as cited in Boyle 2019). The South Florida/Caribbean Network, in contrast, uses a five-year monitoring cycle and sampling occurs within a single year across all plots of the same focal forest community within a park unit.

The South Florida/Caribbean Network uses two reporting formats for delivering output from forest monitoring activities. The first of these is a Forest Vegetation Monitoring Event and Status Report, which includes text, figures, and table summaries from the most recent sampling event in a park. This report is developed for each focal forest type in the monitoring framework during the summer following a sampling event. The second document developed by the South Florida/Caribbean Network is the Status and Trends in Forest Vegetation report. These reports summarize the network's findings over the past three sampling events for a focal forest community and place them in context with previous reporting intervals. These reports also include more in-depth analyses that test for temporal change in key forest vegetation metrics. 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. For both report types, the key metrics are directly linked to the project's monitoring objectives, as stated in the protocol implementation plan (Whelan et al. 2019).

Analysis and Reporting

One way the Cumberland Piedmont Network presents its findings for vegetation monitoring is in terms of ecological integrity. The South Florida/Caribbean Network does not currently use this concept in its implementation, because integrity metrics have not been developed for the forests in

the South Florida/Caribbean Network. As such, there is no modified version of CUPN SOP 13 and the South Florida/Caribbean Network will not produce an ecological integrity scorecard. However, it is the network's hope that ecological integrity indices will be developed in the future. The methods currently employed by the South Florida/Caribbean Network for data analysis and reporting are in SOP FVM12 *Data Analysis and Reporting* (Whelan 2019).

Modifications to Field Sampling

Determination of Forest Community Type

The Cumberland Piedmont Network determines the forest vegetation type by standing in the center of the forest plot and following a dichotomous vegetation key which references the U. S. National Vegetation Classification (US NVC). The South Florida/Caribbean Network follows similar field steps of standing in the center of the plot and rapidly determining the forest community, however, the reference is to the vegetation community definitions that are related to the specific map products that were used for site selection.

DBH Measurements

The Cumberland Piedmont Network uses a 10 centimeter (3.9 inch) dbh minimum stem size for identifying trees that will be tracked over time. The South Florida/Caribbean Network in contrast will tag and track individual stems equal to or greater than five centimeters (2.0 in) DBH. Small size stems can be far older than might be suspected, may be affected by different drivers than larger trees, and may respond differently to some management actions such as changes in hydrology or fire regime.

In Big Cypress National Preserve, a 10-centimeter (3.9 in) DBH cypress tree was estimated to be approximately 200 years old (T. Pernas personal communication). Mangrove species growth estimates vary from 12 to 35 years (*Rhizophora mangle* and *Avicennia germinans* respectively) to reach a 2 cm DBH in Venezuela (López-Hoffman et al. 2007). In the Everglades, under closed canopy conditions, *R. mangle* seedlings took 6 to 21 years to reach the sapling stage (defined as stem height greater than 85 cm), depending on site nutrient level (Koch 1997). At extremely low nutrient sites, even in open canopy conditions, *R. mangle* seedlings can take an estimated 27 to 61 years to reach the sapling stage (Koch 1997).

In addition, the South Florida/Caribbean Network will record the tree DBH to the nearest 0.1 centimeter instead of rounding DBH measurements to the nearest centimeter. SFCN also added instructions on how to measure DBH of palms.

Measurement of Both Tree and Non-tree Growth Forms

The Cumberland Piedmont Network measures individual trees with a dbh $\geq$ 10 centimeter. The South Florida/Caribbean Network, in contrast, measures trees and large lianas with a dbh $\geq$ 5.0 centimeter and that are clearly rooted in the plot. Large lianas are known to be important in tropical forest. Shrubs, vines and smaller lianas are monitored in the species diversity and cover estimates part of the protocol.

Sampling Crew Logistics

The Cumberland Piedmont Network uses two field teams per season that can work simultaneously, with all operations being managed by the network. The South Florida/Caribbean Network, in contrast, currently staffs only one field crew per year.

Tree Maps

The Cumberland Piedmont Network uses a grid-based method to map the location of tree stems. The South Florida/Caribbean Network, in contrast, measures the bearing and distance from the plot center to the tree stem. This information is used to generate a tree map.

Soil Samples and Voucher Specimens

The Cumberland Piedmont Network protocol includes collection of soil samples and plant voucher specimens. The South Florida/Caribbean Network will not collect soil samples or physical plant voucher specimens. Soil is not being collected because most of our substrate is on limestone and the rest are peat systems. Some specimen collection may occur for identification of unknowns but these samples are destroyed during processing.

Woody Debris

The Cumberland Piedmont Network measures volume of coarse woody debris (CWD) across two transects that bisect a typical CUPN vegetation monitoring plot. In the South Florida/Caribbean Network, however, woody debris sampling will include coarse woody debris (CWD), fine woody debris (FWD), inorganic debris (IOD), litter (LTR), and duff (DUF). Collecting data on these additional sources of woody debris describes the total woody debris volume of a site more accurately. The ratio of CWD and FWD has been used to understand forest site disturbance impact (Krauss et al. 2005). These data are also used to characterize wildlife habitat components, enable better understanding of wildland fire risk (fuel load), and help further characterize the vegetative characteristics of sampling locations. The South Florida/Caribbean Network has chosen to sample these additional elements at all forest sampling locations. We use a three-transect design similar to the design used by the Northeast Temperate Network (Tierney et al. 2016) and the Southeast Coast Network (Boyle et al. 2019).

SOP Modifications

The South Florida/Caribbean Network edited 13 of the CUPN SOPs to provide SFCN specifics (see Table 11 for this information). Additionally, each SOP indicates what has been modified. The Cumberland Piedmont Network has a SOP 09 *U.S. National Vegetation Classification Measure* (White et al. 2011) which describes how to use the U.S. National Vegetation Classification to identify the vegetation community at the sample site. The South Florida/Caribbean Network incorporates community identification in SOP FVM03 *Plot Evaluation, Plot Establishment, and Return Visits* (Shamblin 2019a) and references the site classification to the specific map products that were used to designate the focal forest polygons. Similarly, the Cumberland Piedmont Network has SOP 14 *Recording Species Nomenclature and Data Field Descriptions* (White et al. 2011), which the South Florida/Caribbean Network integrated into SOP FVM07—*Species Diversity and Seedling/Sapling Measurements* (Shamblin 2019b). The South Florida/Caribbean Network also

developed SOPs for the forest sampling design, use of the Haglöf DME Distance Ranger Finder, safety, and documenting revisions.

Literature Cited for Appendix A

- Boyle, M. F., M. B. Gregory, M. W. Byrne, P. Capece, and S. Corbett. 2019. Terrestrial vegetation monitoring in Southeast Coast Network parks: Protocol implementation plan. Natural Resource Report NPS/SECN/NRR—2019/1930. National Park Service, Fort Collins, Colorado. Available at: <https://irma.nps.gov/DataStore/Reference/Profile/2263392> (last accessed December 2019).
- DeCoster, J. K., C. L. Lauver, M. E. Miller, J. R. Norris, A. E. C. Snyder, M. C. Swan, L. P. Thomas, and D. L. Witwicki. 2012. Integrated upland monitoring protocol for the Southern Colorado Plateau Network. Natural Resource Report NPS/SCPN/NRR—2012/577. National Park Service, Fort Collins, Colorado.
- Koch, M.S., 1997. *Rhizophora mangle* L. Seedling Development into the Sapling Stage across Resource and Stress Gradients in Subtropical Florida 1. *Biotropica*, 29(4), pp.427-439.
- Krauss, K.W., Doyle, T.W., Twilley, R.R., Smith III, T.J., Whelan, K.R. and Sullivan, J.K., 2005. Woody Debris in the Mangrove Forests of South Florida 1. *Biotropica: The Journal of Biology and Conservation*, 37(1), pp.9-15.
- López-Hoffman, Laura, Ackerly, D.D., Anten, N.P., Denoyer, J.L. and Martinez-Ramos, M., 2007. Gap-dependence in mangrove life-history strategies: a consideration of the entire life cycle and patch dynamics. *Journal of Ecology*, 95(6), pp.1222–1233.
- Patterson, J. M., and M. Londoño. 2019. Sampling Design and In Office Review—Version 1.0. South Florida/Caribbean Network Standard Operating Procedure NPS/SFCN/SOP—FVM02. South Florida/Caribbean Network, Palmetto Bay, Florida. Available at: <https://irma.nps.gov/DataStore/Reference/Profile/2267809> (last accessed December 2019).
- Shamblin, R.B. 2019a. Plot Evaluation, Plot Establishment, and Return Visits—Version 1.0. South Florida/Caribbean Network Standard Operating Procedure NPS/SFCN/SOP—FVM03. South Florida/Caribbean Network, Palmetto Bay, Florida. Available at: <https://irma.nps.gov/DataStore/Reference/Profile/2267809> (last accessed December 2019).
- Shamblin, R.B. 2019b. Species diversity and Seedling/Sapling Measurements—Version 1.0. South Florida/Caribbean Network Standard Operating Procedure NPS/SFCN/SOP—FVM07. South Florida/Caribbean Network, Palmetto Bay, Florida. Available at: <https://irma.nps.gov/DataStore/Reference/Profile/2267809> (last accessed December 2019).
- Tierney, G., B. Mitchell, K. Miller, J. Comiskey, A. Kozlowski, and D. Faber-Langendoen. 2016. Northeast Temperate Network long-term forest monitoring protocol: 2016 revision. Natural Resource Report NPS/NETN/NRR—2016/1184. National Park Service. Fort Collins, Colorado.
- Whelan, K. R. T., R. B. Shamblin, M. Prats, J. Patterson, M. Londoño, and R. Muxo 2019. South Florida/Caribbean Network forest vegetation monitoring: Protocol implementation plan. Natural Resource Report NPS/SFCN/NRR—2019/XXX

- Whelan, K. R. T., 2019. Data analysis and reporting—Version 1.0. South Florida/Caribbean Network Standard Operating Procedure NPS/SFCN/SOP—FVM12 South Florida/Caribbean Network, Palmetto Bay, Florida. Available at: <https://irma.nps.gov/DataStore/Reference/Profile/2267809> (last accessed December 2019).
- White, R., C. Nordman, L. Smart, T. Leibfreid, B. Moore, R. Smyth, and T. Govus. 2011. Vegetation Monitoring Protocol for the Cumberland Piedmont Network, Version 1. Natural Resource Report NPS/CUPN/NRR—2011/XXX. National Park Service. Fort Collins, Colorado. Available at: <https://irma.nps.gov/DataStore/DownloadFile/515620> (last accessed July 2019).

Appendix B: Field Safety

Users should check for updated versions of the SFCN office Safety SOPs in Z:\Safety\ on the SFCN Florida server. Table B-1 has a list of the Safety SOPs and Job Hazard Analyses (JHAs) associated with this protocol.

Table B-1. Safety SOPs and JHAs. For most recent version of files see Z:\Safety\.

Type	Category	File Name
SOPs	Safety Signout – Float plan	Z:\SAFETY\Float_Plan\((CurrentDate)_SFCN_Float_Plan.pdf
	<i>Go/No-Go Checklists</i>	SFCN_SOPs_with_JHAs\Community_operations\Vehicle GoNoGo Checklist
	SFCN Vehicle (Truck)	CommunityGroup.PDF
	SFCN Airboat	Community_operations\SFCN_Airboat_Go_No_Go.doc
	SFCN ATV	SFCN_SOPs_with_JHAs\Community_operations\SFCN_ATV_Go_No_Go.doc
	SFCN Motorboat	SFCN_SOPs_with_JHAs\Community_operations\SFCN_(Boat Name)_Go_No_Go_Checklist_Community.docx
	Radio	SFCN_SOPs\Community_operations\Radio_ID_sheet.xls
JHAs	Hiking	SFCN_SOPs_with_JHAs\JHAs\Community Group JHA's\JHA_Hiking.docx
	Truck	SFCN_SOPs_with_JHAs\JHAs\Community Group JHA's\JHA_Truck.docx
	Airboat	SFCN_SOPs_with_JHAs\JHAs\Community Group JHA's\JHA_Airboat.docx
	Motorboat	SFCN_SOPs_with_JHAs\JHAs\Community Group JHA's\JHA_Motorboat.docx
	ATV	SFCN_SOPs_with_JHAs\JHAs\Community Group JHA's\JHA_ATV.docx
	Helicopter	SFCN_SOPs_with_JHAs\JHAs\Community Group JHA's\JHA_Helicopter.docx

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.

NPS 910/166718, January 2020

National Park Service
U.S. Department of the Interior



[Natural Resource Stewardship and Science](#)

1201 Oakridge Drive, Suite 150
Fort Collins, CO 80525