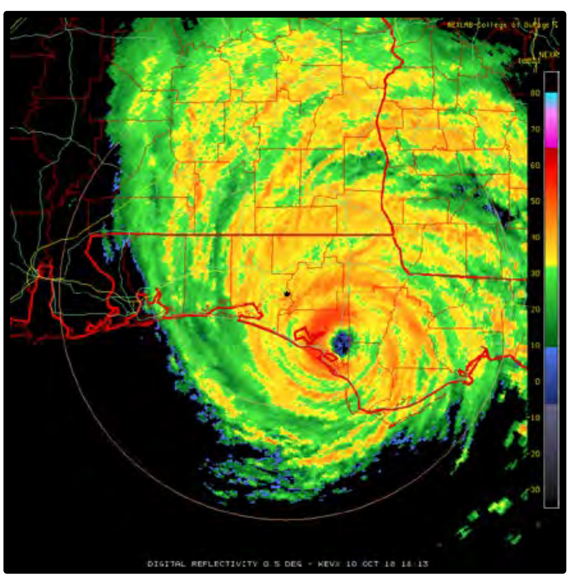
Phase 1: Rapid Assessment and Evaluation Of Restoration Options at State Parks Affected by Hurricane Michael
Task Assignment No.: FN-016
Contract No.: 10109



Draft Interim Report to the Florida Park Service
Department of Environmental Protection

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Overview

Introduction

On October 10, 2018 Hurricane Michael made landfall near Mexico Beach, Florida as a Category 4 storm. The track of Hurricane Michael generally paralleled the west side of the Apalachicola River. FNAI estimates the storm affected about 3 million acres in Florida with sustained gusts of 64 mph. Seven state parks were affected. These parks have been variably affected, with damage to natural communities ranging from minor to catastrophic.

The seven parks with significant damage to be considered in this document include:

1. Florida Caverns State Park
2. Torreya State Park
3. Falling Waters State Park
4. Three Rivers State Park
5. Dr. Julian G. Bruce St. George Island State Park
6. T. H. Stone Memorial St. Joseph Peninsula State Park
7. St. Andrews State Park

To address the immediate challenges posed by Hurricane Michael, DEP assigned the following tasks to FNAI as Phase 1: Rapid Assessment and Evaluation of Restoration Options at State Parks:

Task 1. Rapid assessment of timber salvage options at affected state parks: Knowing that timber loses its value quickly after being downed by a storm event, FNAI will conduct site assessments and recommend, by park and habitat type, management actions that will benefit these natural communities such as salvaging the downed timber versus allowing all or portions of it to remain in place. This recommendation will be based on factors including:

- Risks to imperiled species and biodiversity.
- Potential impacts to other natural resources (vegetation, soils, water quality, etc.)
- Long-term management considerations, particularly the effects on prescribed burning regimes.
- Financial benefits of salvage logging.
- Aesthetics and the ability for the public to utilize the areas for the purposes pre-hurricane.

Task 2. Rapid post hurricane damage assessment: FNAI will gather available data on imperiled species locations and habitat (BIOTICS database, DRP data, Cooperative Landcover, etc.) within the state parks affected. FNAI will conduct a post-storm aerial imagery analysis followed by on-site reconnaissance to determine the condition of resources at risk that cannot be attained by aerial imagery review and also to field validate aerial photo interpretation. FNAI will then map current habitat conditions and resources at risk for each park, by natural community, in order of priority as defined by the DEP project manager. FNAI will develop a rapid assessment field form to evaluate storm damage and validate aerial interpretation.

Task 3. Site restoration evaluation: For the resources encompassed by the affected parks, FNAI will produce a short review of the background conditions, current conditions, resources at risk, and evaluation of the potential restoration actions. In addition, FNAI will conduct a literature search and interviews with leading scientists/land managers regarding the restoration of hurricane impacted natural communities along the Gulf Coast and Eastern Seaboard, where applicable. The products from Task 2 will be used to determine existing conditions and evaluate potential restoration actions. Then all reasonably feasible actions will be analyzed based on the best available science and the potential of the action for adverse or beneficial effects to the parks missions, goals, and objectives as well as the current needs based on the emergency status created by Hurricane Michael.

Task 4. Park staff discussion / education: FNAI staff shall participate in two events (such as District 1 Park managers meeting) to:

1. help inform and educate park staff on the general successional effects of a natural disaster and how that relates to desired future conditions in their natural communities, and
2. Present the findings of this first phase of analysis.

Literature review of Impacts of Hurricanes and Restoration Efforts in the Southeast

Impacts on Natural Resources from Salvage Logging

Salvage logging can cause long term ecological damage, especially in western forests with historically longer periods between disturbance events (Lindenmayer et al., 2004). In the eastern U.S., results have been less obvious, possibly due to salvage operation techniques, more frequent disturbance regimes, different environmental conditions, and perhaps other factors.

In the western U.S., salvage typically is conducted after wildfire. In the southeastern U.S, salvage is generally conducted post hurricane (or tornado). Studies generally indicate that moderate intensity of salvaging can have beneficial or negligible effects. Light salvage following storms in forests with moderate damage has been shown to create microsites which increase diversity in environment and vegetation post treatment, compared to unsalvaged sites (Peterson and Leach 2008). Another study found that "micro-relief" created by pit and mound topography from uprooting of windthrown trees, and shade from salvage slash debris and remaining overstory trees created a mosaic of environmental conditions (Elliott et al. 2002). Peterson and Leach (2008) found that two years after a storm herbaceous cover and species richness, and tree seedling density and species richness, did not differ between salvaged and unsalvaged areas. Brooks and Stouffer's (2010) results suggest that three years after the disturbance, salvage logging appeared to have no negative effect on occupancy of Bachman's sparrows.

The effects of salvage logging after hurricane impacts are poorly understood. There is some support in the southeastern literature that "hurricane thinning" and low to moderate intensity salvage can improve stand conditions in some cases where stands are overstocked. High intensity salvage logging can result in heavy soil disturbance which is likely to result in erosion which may inhibit plant succession, benefit weedy or exotic plant species, and negatively impact desirable groundcover species. The amount of disturbance to the ground cover can vary widely depending on the intensity of the salvage removal, type of equipment used, environmental conditions at the time of salvage, and resource protection measures that are put in place. Therefore, it is important that clear and comprehensive guidelines be set in advance of operations (Stanturf et al. 2007) and that the implementation is monitored for adherence to the guidelines.

Important Considerations Regarding Salvage Logging

When assigning salvage potential for a site, the logging feasibility, potential resource impacts, level of stocking, and condition of the timber should be considered (Baker and Shelton 1998 a,b,c). Also to be considered are the values at risk over the short-term (up to 2 years post-hurricane) from other factors such as fungal stains, decay organisms, and boring insects (Stanturf et al. 2007). Many have suggested a prompt salvage in one operation to reduce the vulnerability of residual trees to bark beetles, borers, and fungi. It is also important to put in place guidelines that minimize logging damage to residual trees, particularly high-value broadleaves (e.g., Meadows, 1993).Following Hurricane Katrina, tree clean-up was more lucrative than salvage logging, leaving a shortage of qualified wood workers for salvage (Janet Anderson, personal communication, 2006). Several factors can limit the ability to capture pre-hurricane value from salvaged pine timber, including a depressed market caused by the large quantity of salvaged material and the rapidity of fungal stain development (Stanturf et al. 2007).

Fire Risk and Storm Debris

Fuel reduction is a primary concern of land managers and driver of salvage harvest in a post-disaster landscape. Severe wildfires and insect outbreaks create pulses of dead trees and initiate a process of post-disturbance fuel succession that may affect future fire behavior and effects (Agee and Huff, 1987; Passovoy and Fulé, 2006; Kulakowski and Veblen, 2007; Monsanto and Agee, 2008, Peterson et al. 2015). Although the notion of a post-hurricane increase in fire hazard has been hypothesized in several ecological studies of hurricane impacts (Webb, 1958; Craighead and Gilbert, 1962; Putz and Sharitz, 1991; Wade et al., 1993; Loope et al., 1994), there are no empirical contemporary data to support the hypothesis. However, Liu et al. 2007 did document an increase in *historical* charcoal amount following storm events in sediment cores in Alabama.

Wildfire hazards are greater in pine dominated forests, but no major wildfires have occurred in southern forests following hurricanes in the last 50 years (Wade 1991). However, as Myers et al. (1998) pointed out, this could simply be the result of fire suppression efforts and fragmentation of the modern day landscape. Downed logs are often considered a fire hazard, but they have been found to provide longleaf pine seedlings refugia from fire (Hermann, 1993). The effects of downed trees creates both an amplifying and buffering effect of fire behavior which co-occur in a spatial matrix (Cannon et al. 2019). Even so, efforts to create defensible space in wildland urban interface (WUI) areas, remove impediments to prescribed burning, and allowing for more effective direct attack on wildfires by removing impediments to heavy machinery are likely warranted as precautionary measures. Additionally, removing large trees and brush in close proximity to control lines and park boundaries, may reduce smoke in adjacent neighborhoods and reduce the chance for escaped fires.

Damage Assessment Overview

During the damage assessment we (FNAI) found damage to be highly variable among locations, depending on orientation to the path of the storm, topography, distance to river corridors, and habitat type. Because damage to natural communities is difficult to quantify, we used percent downed trees and percent canopy cover as surrogates to estimate storm impacts.

To help understand the degree of change in community structure, we pooled data from 699 natural community plots previously collected by FNAI from conservation areas in the Florida Panhandle. FNAI natural community plots collect a wide variety of species composition and forest structure metrics in 20 meter radius plots. We averaged each variable (e.g., canopy cover, shrub cover, herb cover), from these 699 plots (by natural community type) and utilized these averages as reference condition (before storm values) in a comparison to the data collected from the 105 post-storm plots. This provides a measure of the degree of damage from the storm.

Percent downed trees ranged from less than 10% to ~80%. Percent canopy damage ranged from low (around 15% at St. George) to very high (73% at Florida Caverns) (Figure 1).

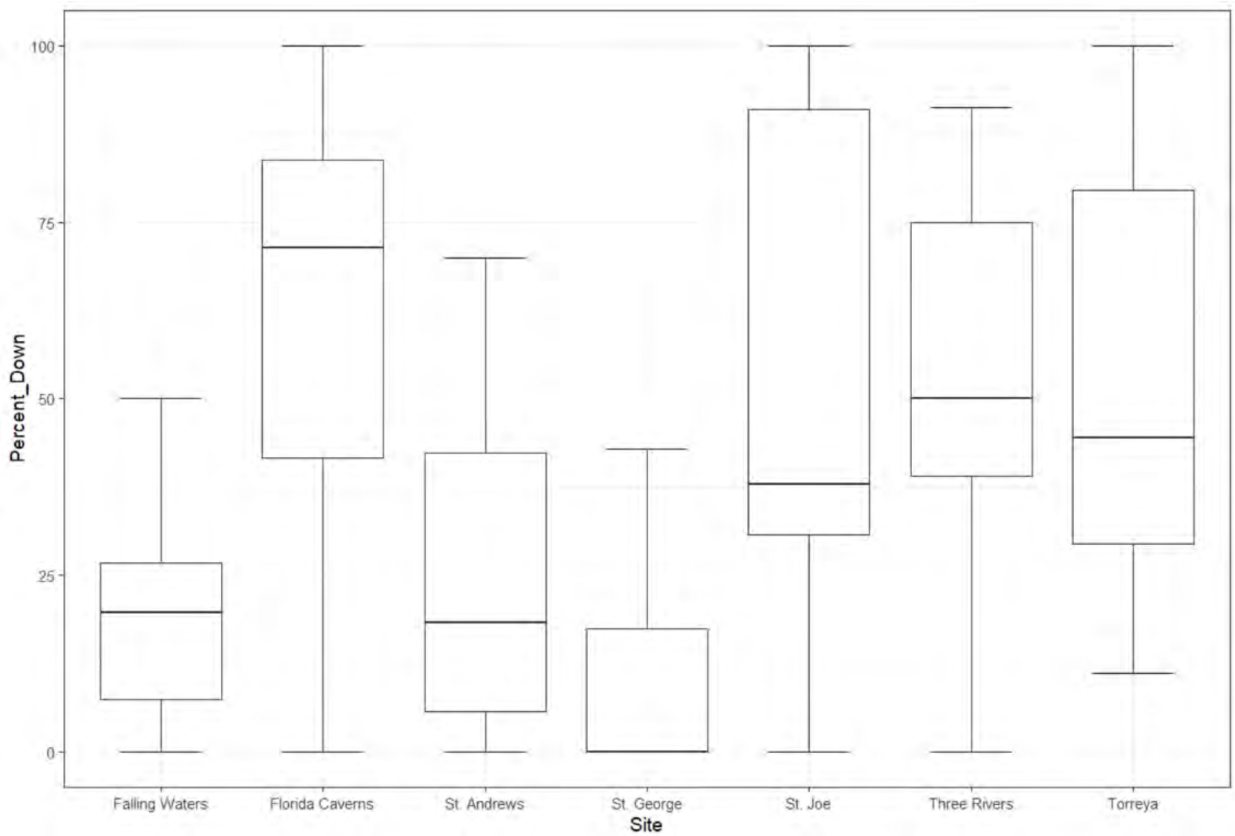
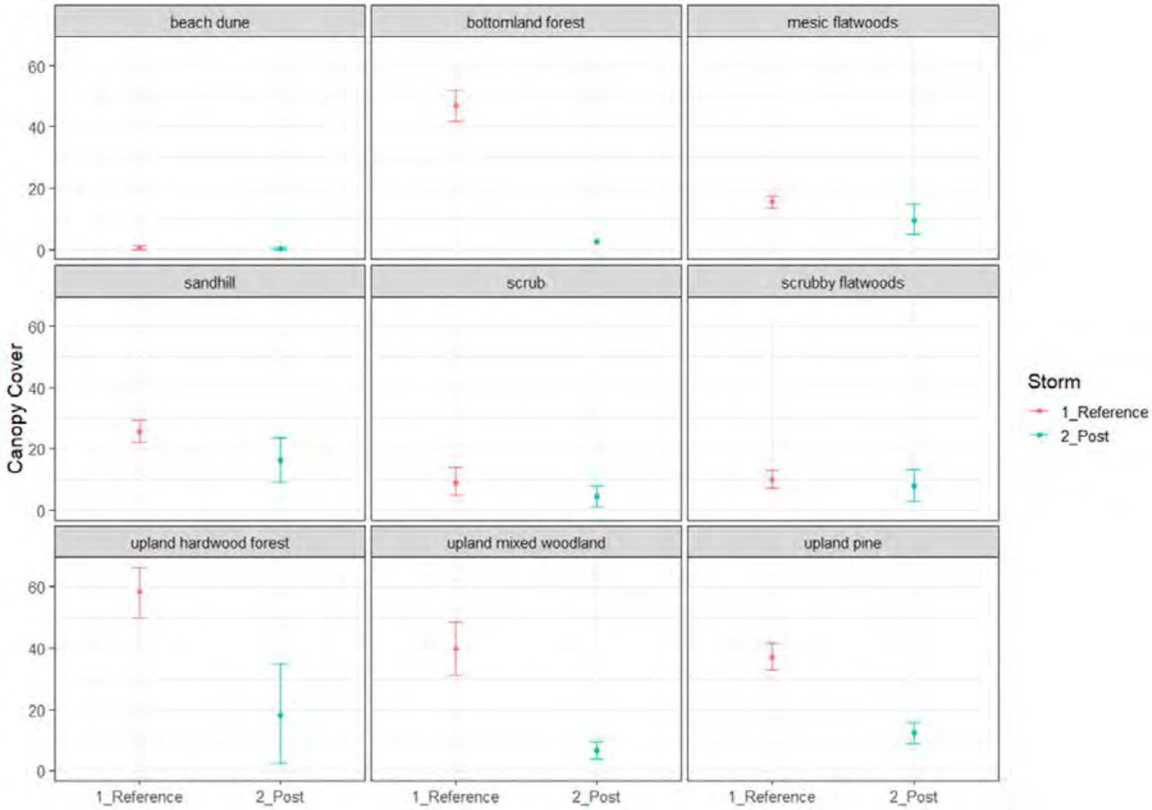
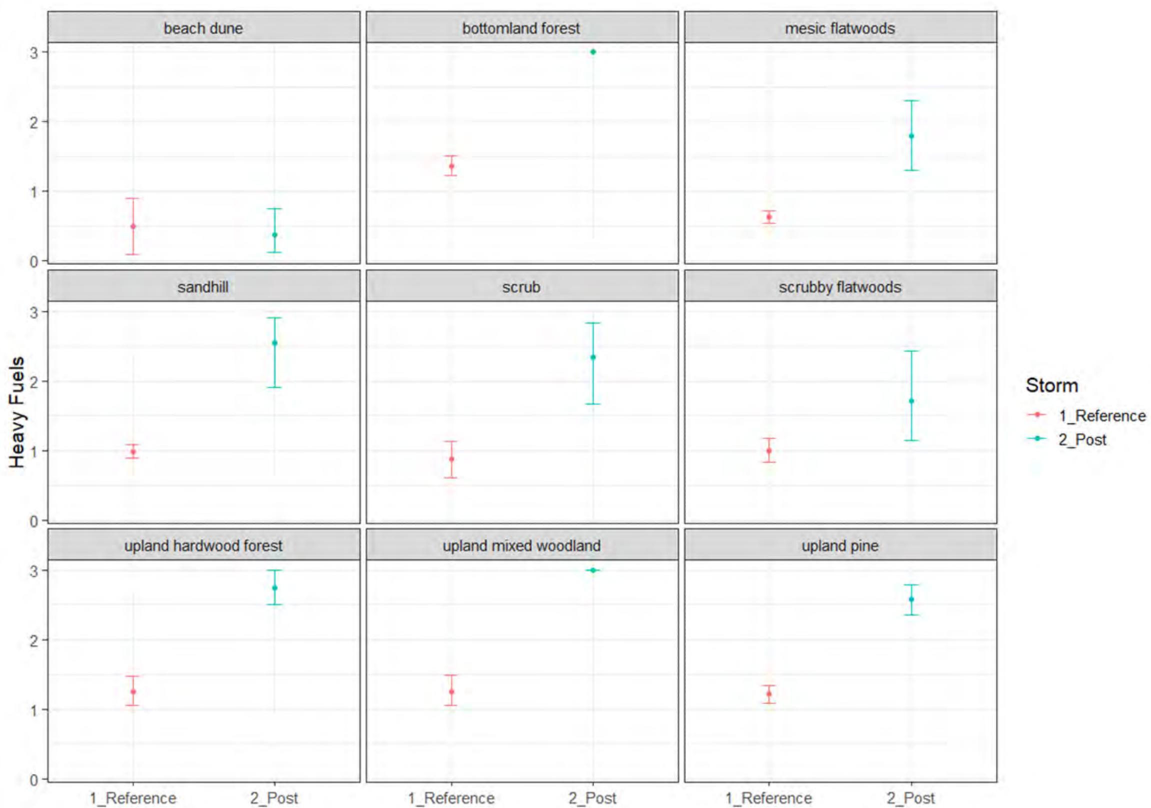


Figure 1. Box plot of percent of trees down in plots.

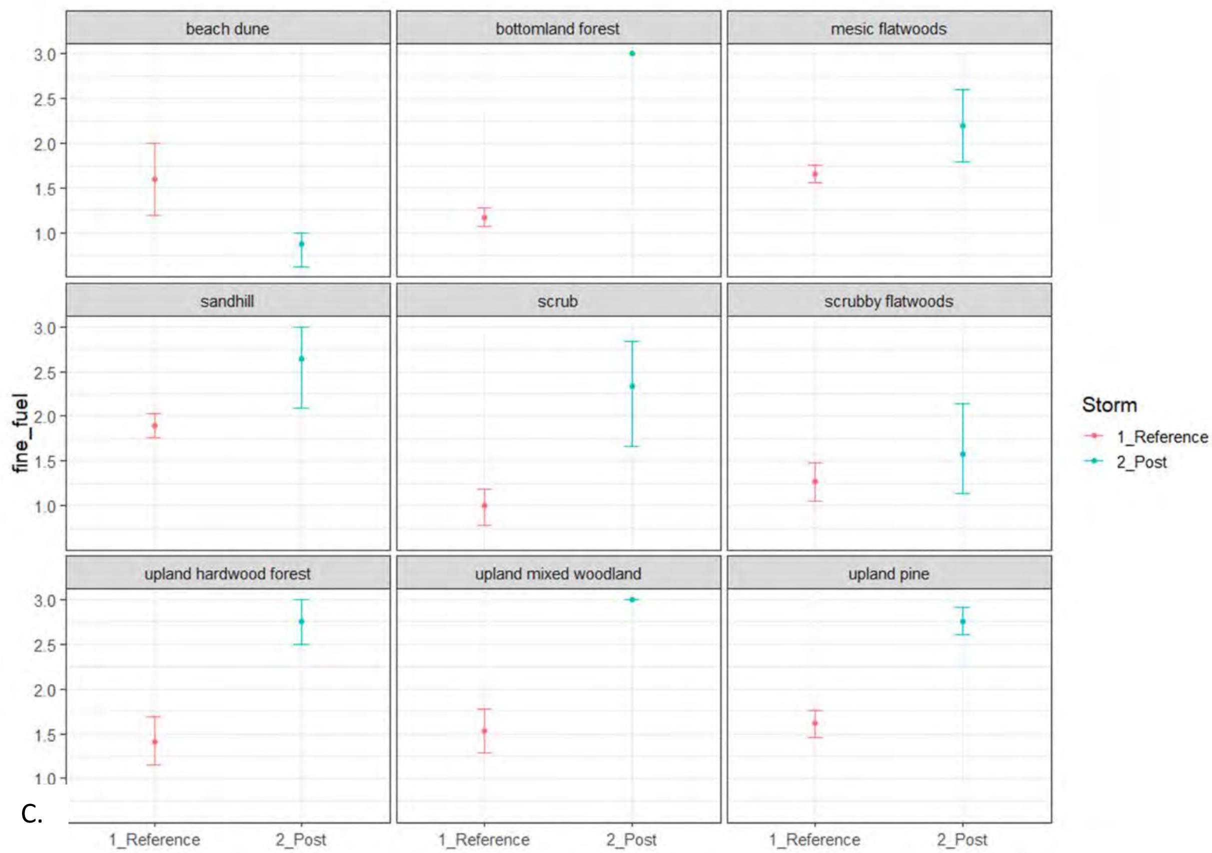
We found canopy cover was drastically reduced, but this varied by natural community (Figure 2A). We found light and heavy fuels generally increased, except in beach dune communities where fine fuels were reduced (Figure 2B and 2C). Medium fuels also increased in most habitats, but the results were less notable. Many natural communities shifted from low to moderate or high in terms of heavy fuels after the storm (Figure 2B). In some cases, the wide degree of variability in the damage measured can be seen in large confidence intervals.


beach dune
bottomland forest
mesic flatwoods
sandhill
scrub
scrubby flatwoods
upland hardwood forest
upland mixed woodland
upland pine
Canopy Cover
0
20
40
60
1_Reference
2_Post
Storm
1_Reference
2_Post

A.


beach dune
bottomland forest
mesic flatwoods
sandhill
scrub
scrubby flatwoods
upland hardwood forest
upland mixed woodland
upland pine
Heavy Fuels
0
1
2
3
1_Reference
2_Post
Storm
1_Reference
2_Post

B.



C.

Figure 2. A.) Canopy cover reductions from reference pre storm conditions B.) Change in heavy fuels ranked high, medium, and low as compared to reference conditions. C.) Change in fine fuels ranked high, medium, and low as compared to reference conditions.

The scale and severity of Hurricane Michael impacts varied by natural community type. We used dNDVI (see Task 2: Rapid Damage Assessment) to estimate landscape scale effects to natural communities in the seven affected parks (see further sections for more detail on this process). Sandhill has the highest amount of acreage affected with over 4,000 acres impacted. However, only about one quarter of that was characterized as severe or catastrophic damage (Figure 3). Over 3,500 acres of slope forest was impacted by the storm, with nearly 60% characterized as severe or catastrophic. Upland pine was even more disproportionally affected by severe or catastrophic impacts with nearly three quarters of its acreage categorized as severe or catastrophic. Other natural communities which experienced high proportion of damage as compared to their acreage include upland mixed woodland, floodplain forest, upland hardwood forest, bottomland forest, and alluvial forest. Those which seem to have been more resistant to damage include scrub, scrubby flatwoods, wet flatwoods, and coastal grasslands. While dNDVI is a remote sensing method which has multiple sources of potential error, these estimates compare well with our on the ground observations and the canopy loss findings (Figure 2A) measured in plots.

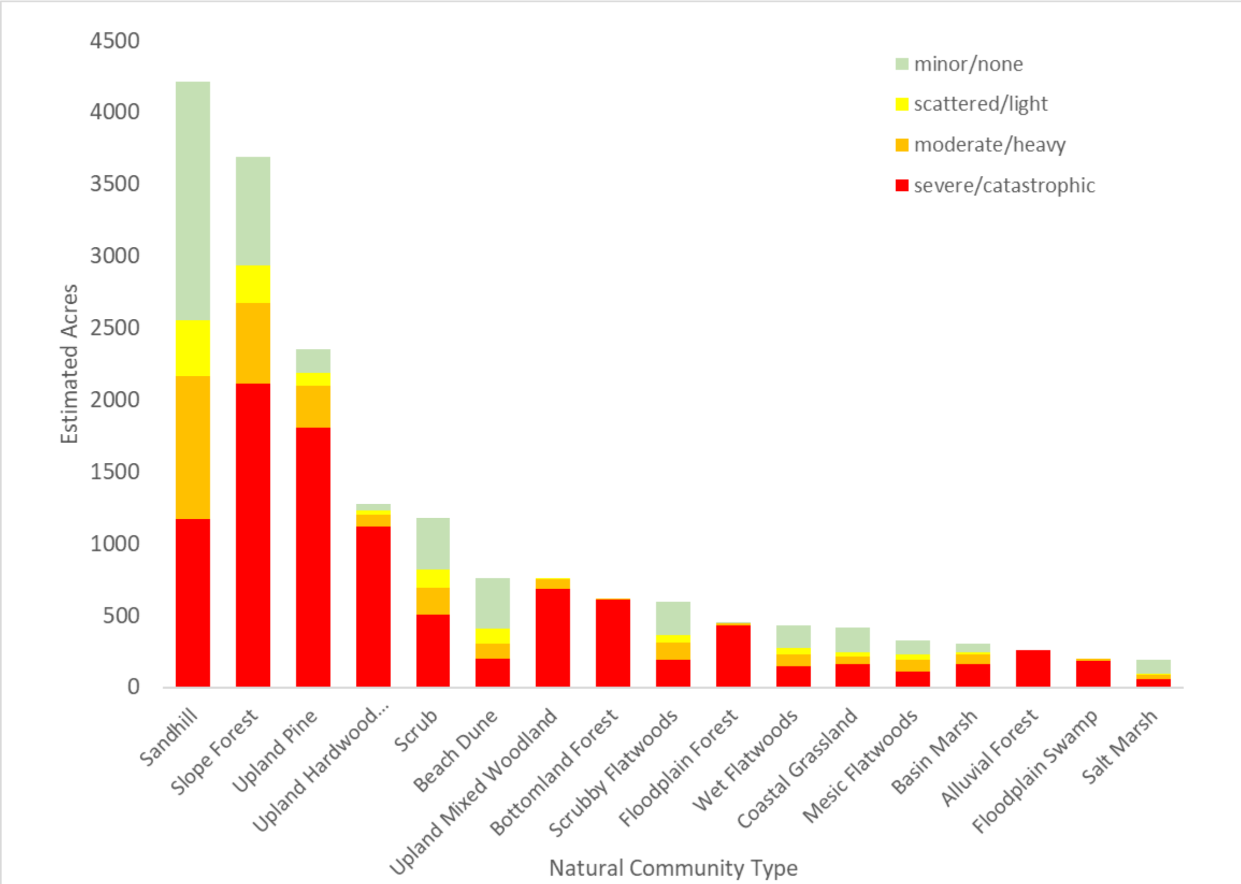


Figure 3. dNDVI estimates of damage to natural communities in the seven parks affected by Hurricane Michael.

Process for Rapid Assessment of Restoration Options

Due to the nature of hurricane damage, it is likely that some form of mechanical operations (such as tree removal) will have to be considered in order to conduct safe and effective restoration actions. The scale of damage in a given area will influence management actions considered. For example, if the damage is minor to moderate and generally isolated in small pockets or of small scale, park staff or special teams can likely remediate the damage in house to allow for prescribed burning. Seeding and planting will probably not be needed in small scale sites, except along main roads or other park infrastructure to enhance visitor experience. If the damage is moderate to severe and occurs across a majority of management unit (or a large area and restoration deemed appropriate) commercial timber operations may need to be considered to allow for safe restoration activities.

In order to streamline decision making regarding which areas to be considered for Task 1 (timber evaluation) and Task 3 (evaluation of restoration options), FNAI developed a process to assess which sites may be candidates for restoration (Figure 4). Sites that could be restored using active management (seeding/planting, prescribed (Rx) burning, or mechanical removal, including timber harvest) were considered on management unit level.

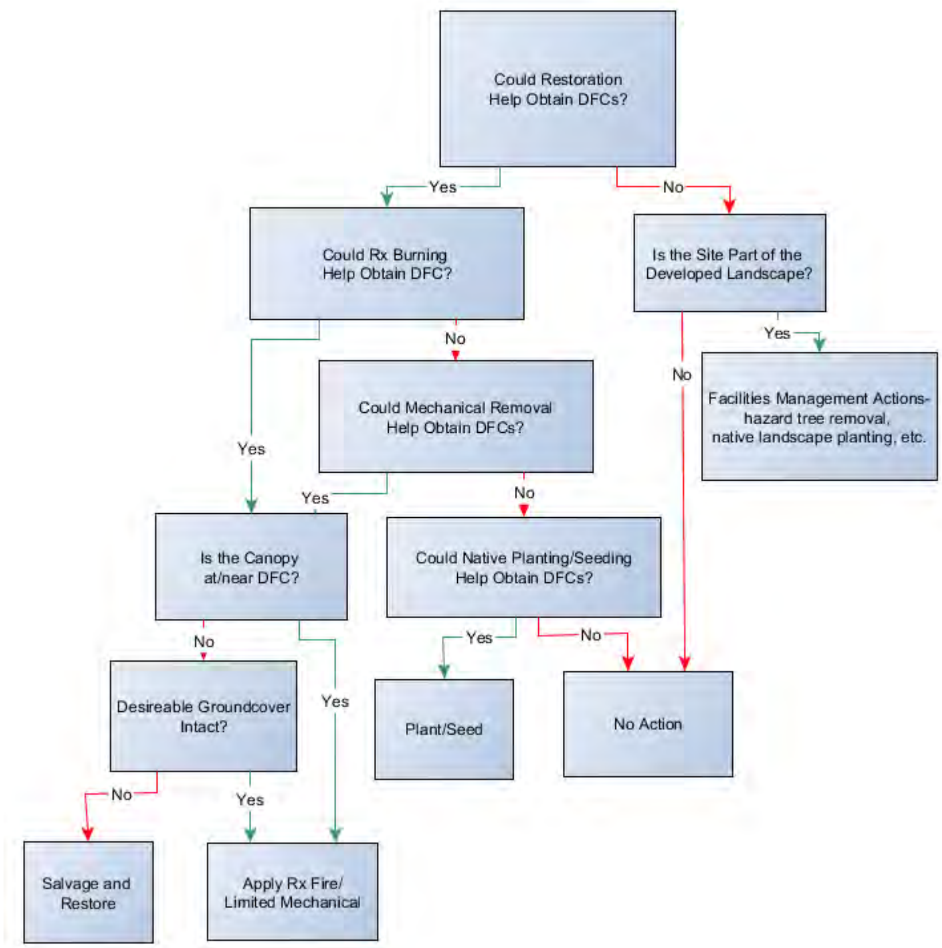


Figure 4. Rapid Restoration Assessment Conceptual Model.

To facilitate the process for considering commercial timber operations for restoration actions, FNAI developed the Rapid Restoration and Assessment Matrix (RRAM), a structured decision making and prioritization tool. RRAM is intended to streamline the decision making process while ensuring all park values and management priorities are considered in a structured, repeatable, and transparent fashion.

The RRAM is a coarse scale filter that helps prioritize management units where large scale restoration actions can help attain desired future conditions (DFCs) and will likely have multiple benefits and few negative impacts to park resources. Because resources and time are limited to conduct meaningful large scale restorations, prioritization of available sites is critical. In general, sites will score highly and therefore be recommended for prioritization if they meet multiple objectives. This assessment tool references the DFCs as defined in the parks' management plans (refer to the Natural Communities section of each park's plan).

When considering large-scale restoration actions, the goals of the park manager are to avoid impacts and/or improve current conditions for natural and cultural resources; restore habitats to DFCs; mitigate hazards created by the storm; and improve visitor experience. The RRAM considers actions at the management unit scale using 12 primary considerations that address these goals: natural communities, imperiled species, soils, special natural features, management plan goals, free park services, timber harvest values, cultural resources, logging feasibility (road access, special considerations, etc.), visitor experience, fire risk, and benefit to adjacent landowner.

In order for a unit to score highly, it must perform well in all considerations. In management zones selected for restoration, best management practices (BMPs; e.g. avoidance of streams, cultural sites, T&E species, etc.) will apply, however, sites that score highly in the RRAM will have very few items to mitigate and so operations should only experience minor modifications based on BMPs.

The RRAM provided an assessment of net gain, generalized as the net greatest benefit of the actions being considered, when weighed against the risks and potential impacts. Final recommendations for each site were based on available scientific literature, other publications, field assessments, and expert input. Fine scale, site specifics- details for each management unit's restoration plan may be considered in Phase 2 and take place after timber operations conclude (or after the 90 day period considered in Phase 1).

General Recommendations

Few tools are available to mitigate storm damage in natural areas. We recommend prescribed fire as the primary tool to mitigate increased fuel loads and facilitate tree seedling regeneration and ground cover recovery. However, in some cases additional fuels reduction may be needed to conduct safe prescribed burns or to mitigate hardwood encroachment and the spread of invasive species. Management zones such as plantations and areas with very high canopy loss, and where natural regeneration to desired conditions is not likely, may require mechanical options to jump start progress towards desired conditions. Heavy mechanical work, such as salvage logging, should be avoided in areas where intact groundcover is present, unless the degree of storm damage is so extreme that prescribed fire cannot be safely and effectively applied.

Generally, in management zones where mechanical removal is conducted, pine planting and groundcover restoration will be needed in order to ensure the successional trajectory toward a diverse, open pine habitat structure. In areas where heavy machinery will be used, we recommend great care be taken to develop and use conservative practices that minimize heavy equipment impacts to ground cover and residual live trees. Outside of fire managed zones, natural succession can be aided by exotic plant management and potentially by planting of unique or rare plant species.

However, restoration prescriptions should be considered on case by case basis, and depend on the specific requirements and natural resource features of the management zone. For this reason, we make zone-by-zone recommendations that can be found in the following chapters. Each of the seven State Parks was evaluated separately. The remainder of this document describes the damage assessment (remote sensed and via field survey) and restoration recommendations for each park.

Florida Caverns State Park

Management Context Related to Restoration Activities

Florida Caverns State Park (FCSP) provides for the preservation and interpretation of irreplaceable natural, historic, and cultural resources found within the park for the enjoyment of Florida's residents and visitors, and to provide compatible resource-based outdoor recreation opportunities along the Chipola River (FDEP 2018).

A recent (2018) update to FCSP's management plan examined the compatibility of the park with timber management. The feasibility of harvesting timber was considered in context of the DRP's statutory responsibilities and an analysis of the park's resource needs and values. The long-term management goal for forest communities in the state park system is to maintain or re-establish old-growth characteristics to the degree practicable, with the exception of those communities specifically managed as early successional. The 2018 plan found timber management in the park to be suitable at Florida Caverns as part of the park's resource management and restoration activities (DEP 2018).

FCSP has a number of unique resources to consider in the context of timber harvest. These include karst geologic features, rare species (plants and animals), and unique natural communities that may be negatively impacted by large-scale salvage activities. Terrestrial caves feature an array of impressive and fragile geologic formations and are home to numerous species adapted to subterranean environments (e.g. Tricolored Bats [*Perimyotis subflavus*] and Southeastern myotis [*Myotis austroriparius*]) as well as the outcrops themselves (e.g., wild columbine (*Aquilegia canadensis*). Due to the park's geological history and topography, the property supports numerous rare plants associated with the southern Appalachian Mountains (e.g., may apple [*Podophyllum peltatum*]). The park protects extensive exceptional and rare natural communities along the Chipola River, including upland glade (one of Florida's most imperiled community types), and upland hardwood forest with unique limestone outcrops.

Keeping in mind the guidance of the 2018 management plan and the special conditions that exist as a result of Hurricane Michael, this analysis will consider action and no action alternatives based on the resources at risk, management considerations, financial benefits, and compatibility with the purposes of the park through using the RAMM tool.

Task 1: Rapid Assessment of Timber Salvage Options

The rapid assessment is meant to consider all of the resources potentially affected by hurricane recovery operations using timber removal as the primary tool for site preparation. The first step is for natural resource managers to use the rapid restoration assessment matrix (RRAM) tool to estimate the effect of timber salvage operations on each of the 12 resources and to score those effects in four categories: 1) likely to adversely affect[1], 2) may affect, but not likely to adversely affect[1], 3) may benefit, but not likely to significantly benefit and 4) likely to benefit. Category 1 received a value of -2 (most negative),

[1] Similar to, but not the same as the official determinations for Section 7 designations under the Endangered Species Act

category 2 received a value of -1, category 3 was 1, and category 4 was 2 (most positive). Neutral or mixed positive and negative were rated 0.

We ranked management units based on their total RRAM score, with the highest values representing the total number of positive benefits of treating a given unit. Because there is some uncertainty in the values, and, to test the sensitivity of the outcomes to the weight given to each element, we weighted natural resources related values, fire risk related values, and timber related values by multiplying these values by two. The management units with the most positive benefits of salvage logging remained similar under these different weighting scenarios, inferring that the top units performed well across categories and were not subject to high degree of change depending on the weight of different values (Figure 5). Based on the below analysis, the units recommended to be considered for salvage operations were 1, 2, 3, 4b, 5, 7, and 8. We recommend no action for commercial timber for the remainder (75% of the total) of the units; although all areas near public use areas will need hazard tree reduction. We recommend salvage harvest continue along park roads and facilities where trees pose a hazard. The highest scoring units (Figure 5) have low impacts to natural and cultural resources, timber value and feasibility, and WUI interface and hazard mitigation benefits. No action sites are typically low lying areas which have infrequent disturbance. Table 1 provides scores for each resource that resulted in the final score, by Management Zone.

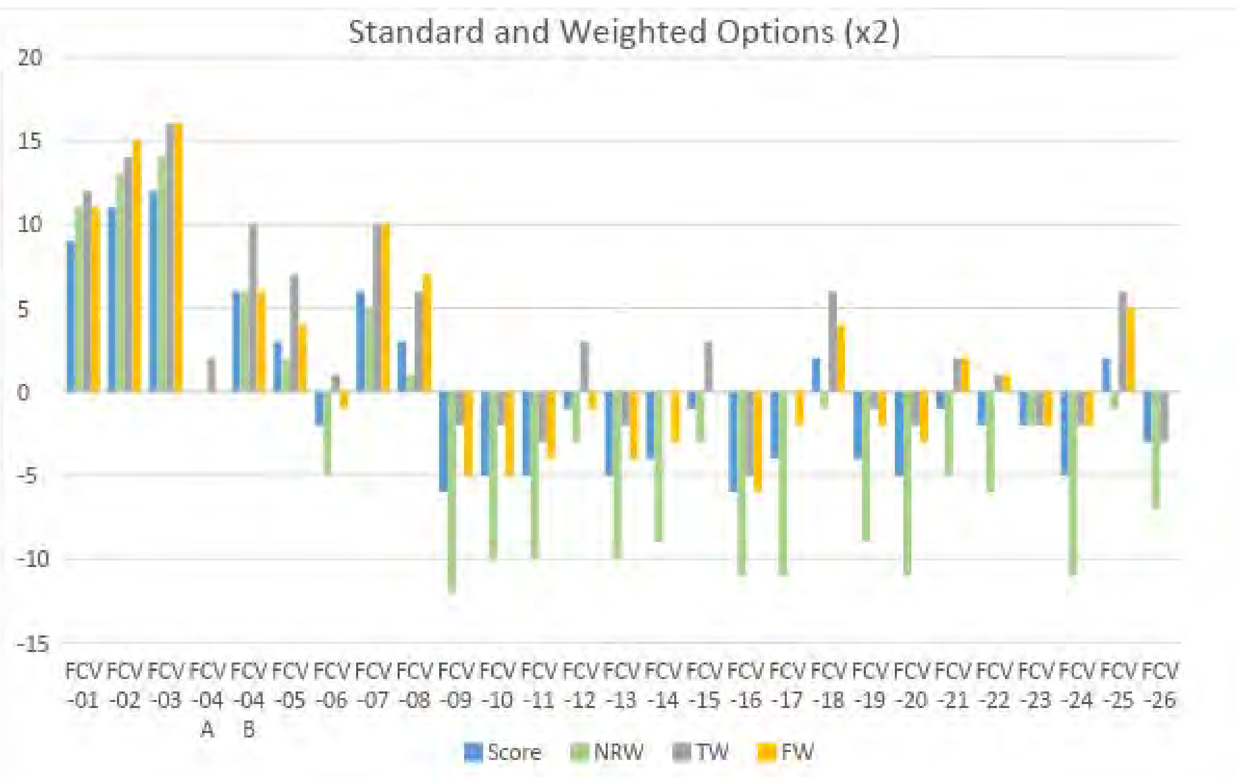


Figure 5. Total points by management unit based on rapid restoration assessment matrix tool. "Score" in blue has an equal weighting across values for all twelve factors. NRW = Natural resource weighted, TW=Timber elements weighted, FW =Fuels and fire risks weighted.

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Table 1: Rapid assessment score for each unit and resource specific weights in FCSP.

	Biotic Factors				Abiotic Factors											
ZONE_ID	NC	IS	So	SNF	MG	FS	TV	CR	LF	VE	FR	BAL	Score	NRW	TW	FW
FCV-01	1	1	-1	1	1	0	1	0	2	1	1	1	9	11	12	11
FCV-02	1	1	-1	1	1	0	1	0	2	1	2	2	11	13	14	15
FCV-03	1	1	-1	1	1	0	2	0	2	1	2	2	12	14	16	16
FCV-04A	0	0	0	0	0	0	0	-2	2	0	0	0	0	0	2	0
FCV-04B	1	0	-1	0	1	0	2	0	2	1	0	0	6	6	10	6
FCV-05	1	0	-1	-1	0	0	2	0	2	-1	1	0	3	2	7	4
FCV-06	-1	0	-1	-1	0	0	1	-2	2	-1	1	0	-2	-5	1	-1
FCV-07	1	0	-1	-1	1	0	2	-2	2	0	2	2	6	5	10	10
FCV-08	-1	0	-1	0	1	0	2	-2	1	-1	2	2	3	1	6	7
FCV-09	-2	-2	-1	-1	-2	0	2	-2	2	-1	1	0	-6	-12	-2	-5
FCV-10	-2	-1	-1	-1	-1	0	2	-2	1	0	0	0	-5	-10	-2	-5
FCV-11	-1	-1	-2	-1	-1	0	2	-2	0	0	0	1	-5	-10	-3	-4
FCV-12	-1	0	-1	0	0	0	2	-2	2	-1	0	0	-1	-3	3	-1
FCV-13	-2	-1	-1	-1	-1	0	1	-2	2	-1	0	1	-5	-10	-2	-4
FCV-14	-2	0	-2	-1	-1	0	2	-2	2	-1	0	1	-4	-9	0	-3
FCV-15	-1	0	-1	0	-1	0	2	-2	2	-1	0	1	-1	-3	3	0
FCV-16	-2	-1	-2	0	-1	0	2	0	-1	-1	0	0	-6	-11	-5	-6
FCV-17	-2	-2	-2	-1	-1	0	2	-2	2	0	1	1	-4	-11	0	-2
FCV-18	-1	0	-2	0	1	0	2	-2	2	0	1	1	2	-1	6	4
FCV-19	-1	-2	-1	-1	-1	0	1	-2	2	-1	1	1	-4	-9	-1	-2
FCV-20	-2	-2	-1	-1	-1	0	1	-2	2	-1	1	1	-5	-11	-2	-3
FCV-21	-1	-1	-1	-1	0	0	1	-2	2	-1	1	2	-1	-5	2	2
FCV-22	-1	-1	-1	-1	-1	0	1	-2	2	-1	1	2	-2	-6	1	1
FCV-23	0	0	0	0	0	0	0	-2	0	0	0	0	-2	-2	-2	-2
FCV-24	-2	-2	-1	-1	-2	0	1	-2	2	-1	1	2	-5	-11	-2	-2
FCV-25	-1	0	-1	-1	0	0	2	-2	2	0	1	2	2	-1	6	5
FCV-26	-1	-1	-1	-1	0	0	1	-2	-1	0	1	2	-3	-7	-3	0

NC= Natural Communities TV=Timber Value VE=Visitor Experience FR=Fire Risk NRW=Natural Resource Weighted
IS= Imperiled Species CR=Cultural Resources MG= Management Goals TW= Timber Elements Weighted
So=Soils LF=Logging Feasibility SNF= Special Natural Feature FW- Fuels and Fire Risk Weighted

Recommended Resource Protection Measures

Management Units 1, 2, 3, 4b, 5, 7, and 8 were identified by the ranking and prioritization as places where some level of timber harvest could be conducted to attain DFCs (e.g. prepare sites for upland pine and groundcover restoration) and where expected positive outcomes outweigh negative outcomes (Figure 6). If timber harvest is planned for these units, we recommend the following practices be implemented to minimize resource damage and increase the likelihood of long term restoration success, should timber harvest be utilized. The following recommendations are for near term actions (less than 90 days as defined by the task agreement) and should be considered in addition to standard DEP and Florida Department of Agriculture's BMPs for public lands timber harvest. The primary goal is to conduct removal of downed trees and excessive fuels/hazard trees with the least possible soil disturbance.

1. Remove downed/>60% leaning merchantable and hazard timber from roadside, facilities, campsites, and fire breaks within 100 feet of the roadbed where possible.
2. Where timber is not accessible from roadside, use minimum impact techniques to reduce collateral damage to soil, groundcover, and live trees as recommended by logging operations specialists. These should include:
    - Use of low ground pressure equipment such as dual-tire skidders, tracked machines or special techniques such as "mat-logging" or "shovel-logging." Promptly remove the shovel-mat skid trail when no longer needed. If logs/trees are completely buried in the soil, then leave them in place to avoid further soil disturbance. Do not excavate stumps or soil when installing or removing the shovel-mat skid trail.
    - Concentration of skid trails to as small an area as possible and minimize the number of trails on a given site. Keep skid trails to 1 skidder wide.
    - Restricting skidder and other rubber tired equipment operation to roads or skid trails.
    - Planning heavy equipment operations for dry seasons / dry periods only.
3. Clear fire breaks on the northeastern perimeters of units 8, 7, 3 to serve as a haul and working route.
4. Flag, and exclude operations near, cultural resources sites within the distance recommended by DEP cultural resources specialists.
5. a) Retain all live longleaf and shortleaf pines. Retain all pine trees and hardwoods greater than 25" DBH.

    b) Avoid harvesting damaged areas if safe operations require removal of trees as described in 5 a.
6. Avoid use of heavy equipment in upland hardwood area in unit 8 and limestone outcropping in unit 5.
7. Clean all machinery from offsite by high pressure water to remove possible seed sources and introduction of exotics species.
8. Prevent erosion and protect soils from compaction and rutting.
9. Leave scattered non-merchantable medium and large logs. Avoid exposing soils by completely removing litter and debris.

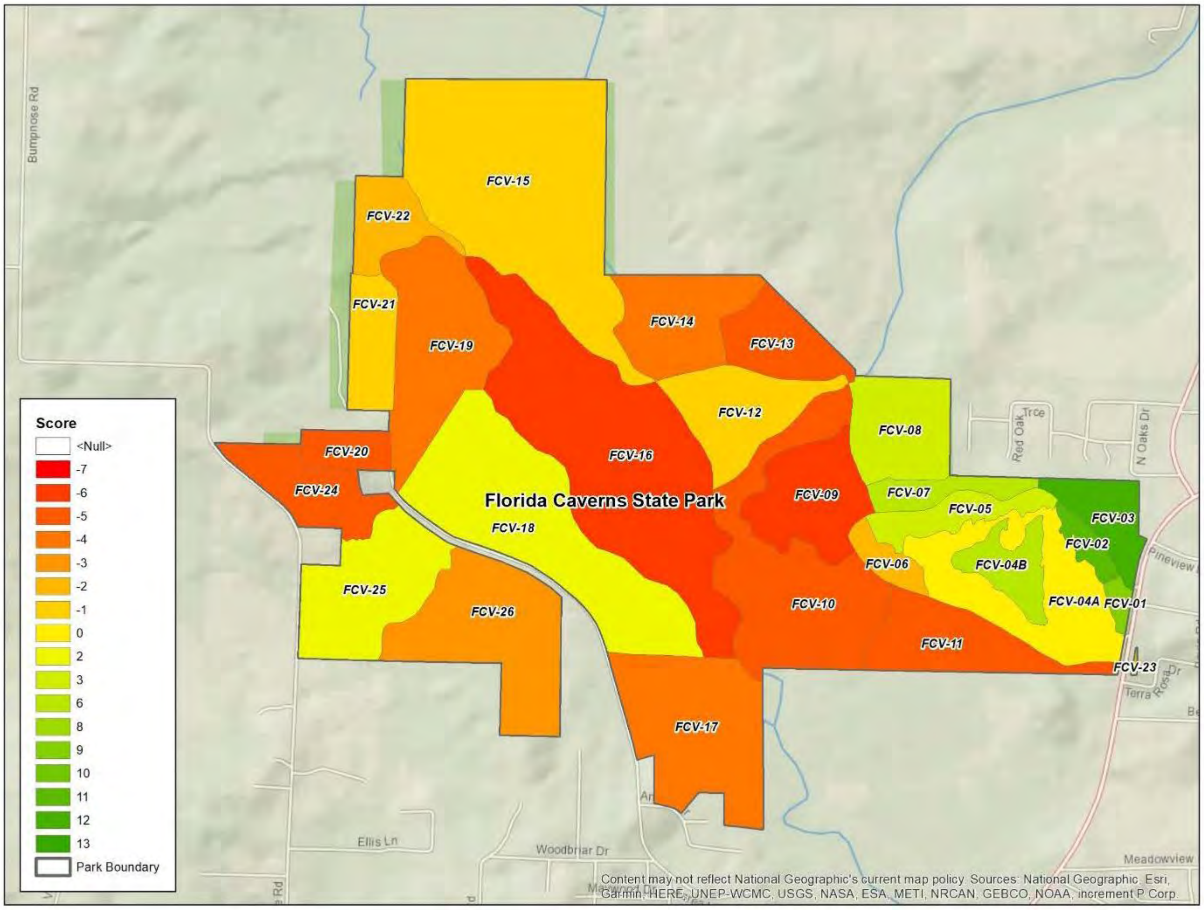

Figure 6. Unit Scores for Florida Caverns State Park.

Task 2: Rapid Damage Assessment

Rapid damage assessment was conducted at two scales: using remote sensing and on the ground with plots and visual observations. First, damage was assessed through remote sensing using normalized difference vegetation index (NDVI). NDVI is a simple graphical indicator that assesses whether the target being observed contains live green vegetation; this has been used effectively to assess storm damage (Wang et al. 2010). Using MODIS satellite imagery, FNAI determined the difference in NDVI (dNDVI) from October 2017 to October 2018 (Figure 7) and then applied the values to natural communities and park boundaries (Figure 8). MODIS satellite imagery provides NDVI values at a 250x250 meter scale. Some factors which need to be considered when interpreting NDVI readings are: 1) areas dominated by grass, standing water, or impervious surface may alter results; 2) other land use changes within the last year (e.g. fire, logging, etc.); 3) actual damage to deciduous trees could be overestimated and 4) trees, especially pines, may not have fully browned. Next, NDVI values were assigned to damage class bins which were created using post storm imagery and U.S. Forest Service hurricane fuels assessment categories (Figure 7).

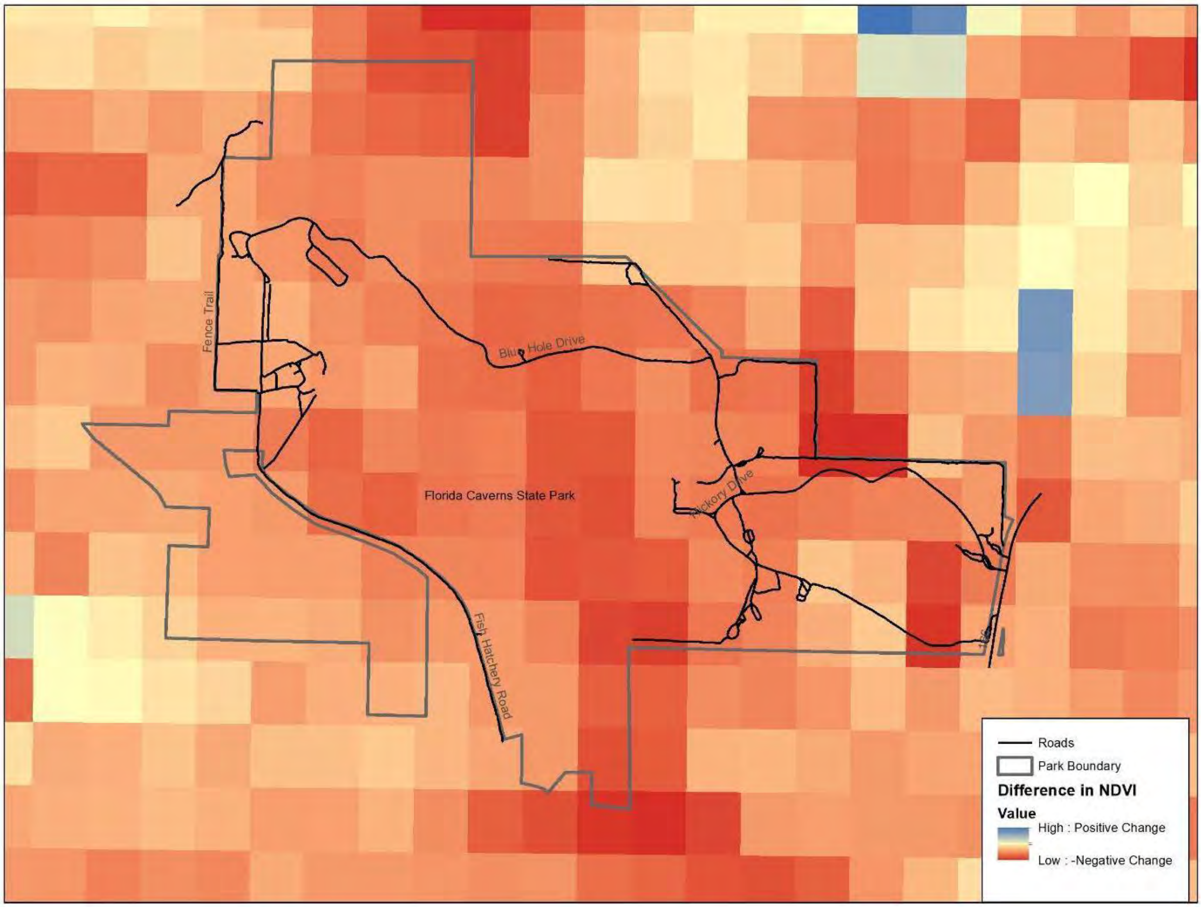

Figure 7. Difference in NDVI (dNDVI) from early-mid October 2017 and early to mid-October 2018. Low values (red) indicate a loss in "greenness" from the year before during the same period, an indication of severity of storm damage. Nearly all the park was severely impacted.

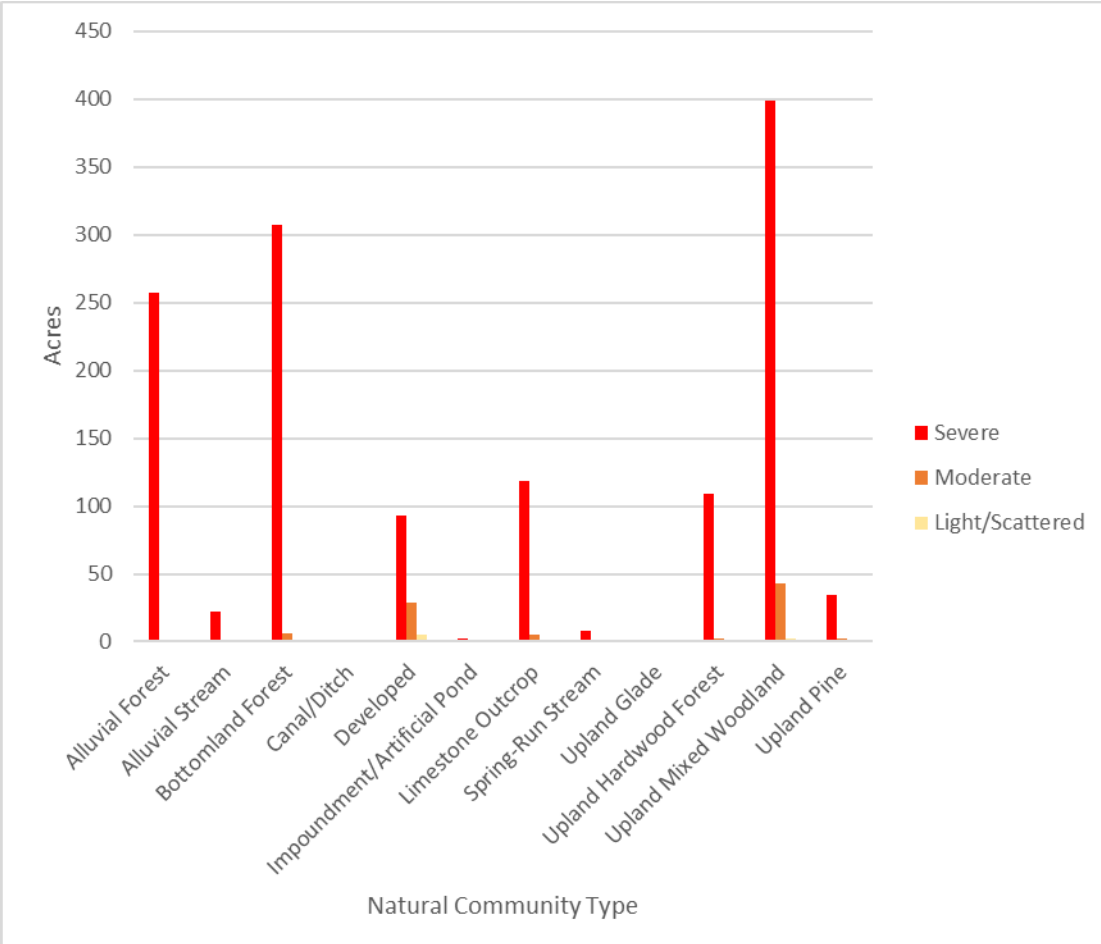

Figure 8. Acres of NDVI estimated damage to natural community by damage class. No acres were placed in the minor/none category.

A field assessment was completed on December 6, 2018. FNAI scientists surveyed accessible areas on foot and vehicle to evaluate habitat conditions that cannot be observed via aerial or satellite imagery. We estimated fuels and other forest structure metrics using standard FNAI natural community plots (See Appendix H for data form and category definitions) and collected photo points at the center of each plot (See Appendix A). Because access and time were limited, we collected non-random assessment plots. The number of reference plots was determined by the range of variability found within each natural community represented. We also limited the scope of our on the ground assessments to natural communities which would have higher restoration potential (e.g. where active management is generally more appropriate such as fire maintained habitats).

Canopy loss was the most profound change observed. Unusually high fuel loads of downed trees are now present. Changes in the understory are likely to occur as a result of increased sunlight to the ground layer. Our plot estimates across all natural communities indicate around 72% of all trees are down, with a minimum/maximum range from 33 to 100% per plot (Figure 9). The damaged trees are both blown down from the roots and/or the stem is broken forming "A frames." Canopy cover is low in all community types, with the highest cover found in upland pine (around 9%), but lower cover in hardwood communities was likely influenced by the additive effect of some normal winter senescence in addition to hurricane effects (Figure 9). Fine, medium, and heavy fuels were assessed as "high" in all plots and litter cover averaged 83% across all plots (Figure 10).

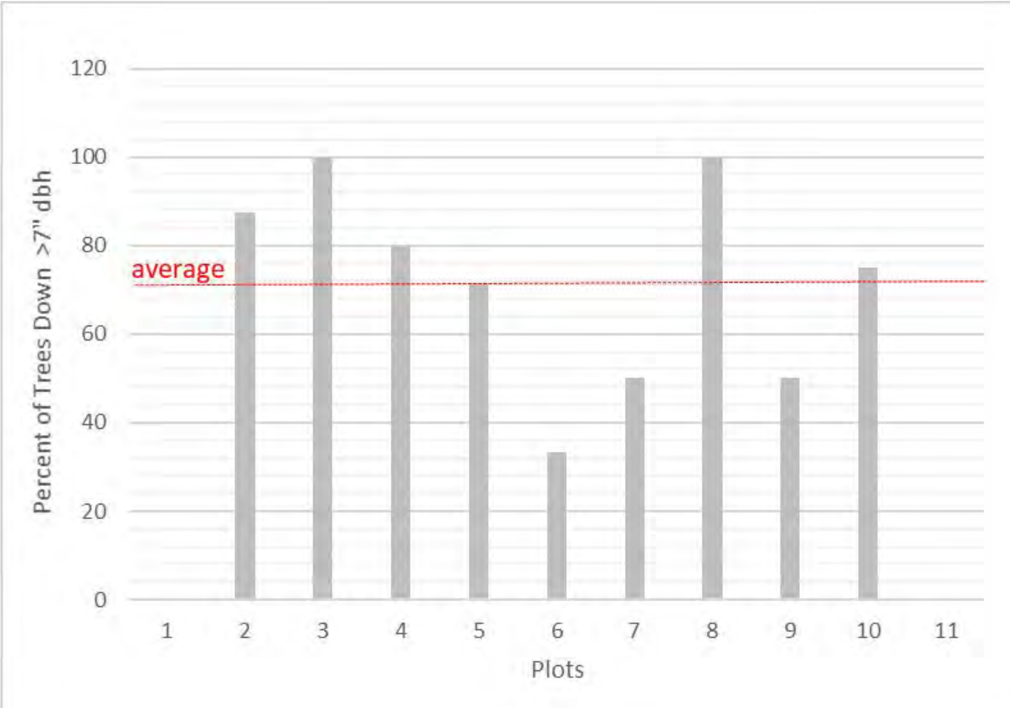

Figure 9. Percent of trees down in plots.

Natural Community	Canopy Height	Canopy Cover	Subcanopy Height	Subcanopy Cover	Pine Basal Area
bottomland forest	52.5	2.5	22.5	20.5	0.0
upland hardwood forest	61.7	2.5	22.5	18.0	2.5
upland mixed woodland	52.5	2.5	22.5	10.5	20.0
upland pine	58.0	9.3	22.5	6.1	6.0
Average	**58.0**	**5.6**	**22.5**	**12.1**	**5.5**
	Fine Fuels	**Medium Fuels**	**Heavy Fuels**	**Graminoid Cover**	**Total Shrub Cover**
bottomland forest	3.0	3.0	3.0	2.5	10.5
upland hardwood forest	3.0	3.0	3.0	2.5	30.5
upland mixed woodland	3.0	3.0	3.0	10.5	30.5
upland pine	3.0	3.0	3.0	2.1	22.9
Average	**3**	**3.0**	**3.0**	**3.0**	**25.2**

Figure 10. Data summary of plots. Height measurements in feet, cover in percentages, pine basal area in ft^2/acre. For "ranked fuels" low is 1, moderate, is 2, and 3 is high relative to DFCs.

At the time of the field assessment, tree removal was already underway at the park, focusing on the immediate needs of clearing trees on and hanging over roads, structures, and staff safety areas (described as Phase 1 by the manager). The entrance to the park and the road in the north leading to the residences were early priorities because of the structural dangers to park infrastructure. The road leading to the rear residences is presently lined with stacked up timber that was removed from the road to give access to those residences. The park entrance directly north of the entrance station and around the two nearby houses is mostly cleared of vegetation following the work that has already been completed (Figure 11). This area, given its public visibility, will likely be an early restoration priority.

Figure 11. Looking south from the park boundary toward the entrance station and residences.

The upland hardwood forest surrounding the Visitor Center has also already been cleared of downed trees near the building, sidewalks, and parking lot (Figure 12). This upland hardwood forest, which was once occupied by large hardwoods, now has an open canopy. Tree replanting of this area may be needed; we recommend an assessment of existing small/understory tree stock to determine whether or not additional planting is needed.

Figure 12. Visitor Center and surrounding forest after Phase 1 clearing. Large southern magnolia tree stump in the foreground.

Longleaf pine habitats

Longleaf pine habitats at FCSP include upland pine and upland mixed woodland. Both of these habitats historically have an open canopy of longleaf pine (*Pinus palustris*) and in the less common upland mixed woodland a mixture of hardwoods (i.e., red oak, flowering dogwood, mockernut hickory) would also be present. Both habitats require fire and have an herbaceous understory (FNAI 2010). Several areas of the park were historically dominated by these pine uplands, notably an area on the west side of Zone 15, portions of Zone 19 near the residences and the campground, Zones 20, 1-3, 5, 4B, 7, and the southeast portion of Zone 8. Most of these areas were visited to assess timber removal possibilities as these areas scored as top priorities in the timber assessment.

Significant canopy damage was observed in all areas we visited, with varying degrees of severity. These uplands represent the most feasible portions of the park for pine salvage removal. The increased sunlight due to the canopy damage may be a long-term benefit to some of these stands, especially in areas where fire has long been absent and the canopy was dominated by off-site pine (loblolly and slash pine) and invading hardwoods (i.e., laurel oak); these stands are currently classified as successional hardwood forest. These areas are potential opportunities for restoration (longleaf and/or desirable herbaceous species planting) once the increased fuel loads (downed trees) have been addressed. Along the entrance road in zones 1-3, 5, 7 and the southeastern portion of Zone 8 are visible examples (Figure 13). In these zones, most of the large hardwood trees appear to have been damaged and many of the remaining standing trees are pines (slash, loblolly, and longleaf pines), including a few scattered longleaf pine observed (Figure 14). Along the property line near the entrance a stand of large longleaf, most of which were blown down, was observed (Figure 15).

Figure 13. The zones along the entrance drive. Trees along the road shoulder have been removed. Pines are the majority of the trees remaining standing in this historic upland pine area.

Figure 14. Longleaf pine (largest tree in center) still standing post-storm near the Beech picnic shelter.

Figure 15. Longleaf pines near the property line just north of the park entrance damaged during the storm.

Hardwood Forests/Upland Glade

There were a number of areas of the park that were not field assessed due to water/time constraints or because of priorities for timber assessment. This does not indicate that the resources in those areas are not valuable, just that timber removal is not likely to be considered for immediate salvage.

In the closed canopied habitats such as alluvial forest, bottomland forest, and upland hardwood forest (see FNAI 2010), the increased sunlight will drastically change the microclimate of these formerly closed canopied forests. The successional changes that will occur over the next 20-50 years in each of these habitats is unknown. Early successional species, such as laurel cherry (*Prunus caroliniana*) and invasive species, such as Japanese honeysuckle (*Lonicera japonica*), Japanese climbing fern (*Lygodium japonicum*), Chinese privet (*Ligustrum sinense*), and Cretan brake (*Pteris cretica*) or Japanese ardisia (*Ardisia japonica*) may show increases in the immediate future. Exotic plant treatments should be considered a high priority in these areas, even within the next 90 days, if operations can be conducted safely. Community structure and composition monitoring would allow us to document and better understand these successional transitions.

During the field assessment the forested wetland habitats (bottomland forest, alluvial forest) were minimally assessed due to the significant flooding from the Chipola River at the time. Significant canopy damage was observed in the areas that were assessed and high water remained in the bottomland forests (Figures 16 and 17). Because of high water and low potential for restoration, alluvial forests were not visited. Canopy damage may appear worse than it actually is because deciduous species are mostly leafless at this time. After leaf out in the spring, the full extent of canopy damage can be better assessed. Aside from areas of public access where safety concerns need to be addressed, we recommend exotic plant treatment and passive restoration (i.e. allow natural succession to proceed).

Figure 16. Flooding along Muddy Branch taken in the bottomland forest along the entrance drive. Flooding extended almost to the upland hardwood forest.

Figure 17. Bottomland forest near the exit to the campground looking toward the main road.

As with the forested wetlands, significant canopy damage occurred in the upland hardwood forests (Figures 12 and 18). These are mixed canopy forests dominated by a diverse suite of species including deciduous trees such as white oak (*Quercus alba*), Florida maple (*Acer saccharum* ssp. *floridanum*), and American beech (*Fagus grandifolia*), and evergreen species such as southern magnolia (*Magnolia grandiflora*), live oak (*Quercus virginiana*) and spruce pine (*Pinus glabra*). In undisturbed condition, the dense canopy of upland hardwood forests and multiple layers of midstory vegetation restrict air movement and light penetration, which maintains high relative humidity within this community. The groundcover is made up of shade-tolerant herbs, graminoids, and vines, several of which are rare in Florida and more common further north (i.e., mayapple (*Podophyllum peltatum*)). Given the significant canopy loss due to Hurricane Michael, the delicate microclimate of these areas will undoubtedly be changed causing unknown effects to the community structure and composition that will need to be evaluated through monitoring of vegetation changes. A concern of note is how the fragile spring ephemerals (wakerobin (*Trillium* sp.), mayapple (*Podophyllum peltatum*), and wild columbine (*Aquilegia canadensis*)) in the ground layer of this habitat at FCSP will respond to the change in light availability. Invasive species are another concern, especially in the areas where limestone outcrops are present. Japanese ardisia was seen thriving and fruiting in the hardwood forest near the Beech shelter (Figure 19) and Japanese honeysuckle was observed in many locations across this habitat type. These forests are sensitive to intensive management because of their rare resources and fragile microclimate and will likely need to recover on their own, aside from areas where downed trees need to be removed for public safety. Where trees must be removed because of safety concerns (i.e., near the Visitor Center and nature trails), leaving as much debris and logs on the forest floor as possible (as opposed to removing these from the site) is recommended. This will help prevent erosion and help build the nutrient-rich soil back up, not only by decomposing but serving to catch falling leaves and hold them in place.

Figure 18. Needle palm (Rhapidophyllum hystrix) in a rich upland hardwood forest in southwest portion Zone 8.

Figure 19. Japanese ardisia observed fruiting after the storm in the southwest portion of Zone 8.

One of the large mayapple populations (near the Hickory Shelter) was visited during the field assessment. This species is not visible this time of year but it was noted that the canopy was only moderately damaged. This and all other rare plant populations should be revisited when it is phenologically appropriate. Limestone outcrops in the vicinity of the mayapple population were also visited and, while sunnier than normal, are intact (Figure 20).

Figure 20. Intact limestone outcrop in Zone 11 with significant canopy damage over it.

The most sensitive habitat at FCSP is upland glade, which was visited by Ann Johnson on January 6th, 2019. Upland glades are mostly herbaceous communities on thin soils over limestone outcrops on steep topography. They occur as small openings in an otherwise forested landscape. Over a third of the glade is currently covered with downed trees (mostly cedars) along its northern side (Figure 21). With the highly sensitive nature of the soil in upland glades, any further soil disturbance is discouraged, especially heavy equipment disturbance. Careful hand clearing of this very small area would be ideal if it is determined that some of the debris is detrimental to this fragile habitat. Populations of sensitive and rare species should be revisited when it is phenologically appropriate to evaluate the populations post hurricane.

Figure 21. Downed cedar trees on the upland glade.

Task 3: Restoration Evaluation

For those areas of the park not being considered for restoration by timber removal, options to consider include: prescribed burning, native planting, native seeding, mechanical removal of vegetation, and chemical control of exotic species (could be conducted in all areas with hazard tree removal). In this document we outlined actions that can be taken in the near term (within 90 days). Many additional actions, such as groundcover restoration and pine planting, will likely occur outside of the near term. This document outlines only the types of actions needed to facilitate the planning and future success of longer- term restoration activities (post 90 days). Near term actions will mainly consist of preparing a site for future restoration actions (e.g. timber or brush removal), except in portions of Unit 3 which have already been cleared. In that area the Park could consider outplanting longleaf and shortleaf pines immediately.

Recommendations Based on Historic and Current Conditions

The sites that have been determined appropriate for timber removal are also the best suited for longer term restoration actions (1, 2, 3, 4b, 5, 7, and 8). Some of the damage resulting from Hurricane Michael created opportunities for restoration of habitats that were already somewhat degraded by insufficient fire and past land use history.

Aerial photography from 1940 indicates that the eastern corner of FCSP (Management Zones 1-3, 4B, 5, 7, and the southeast portion of 8 (Figure 22) has been cleared for a golf course for more than half a century, however the intervening natural habitat fragments suggest these areas were open canopy upland pine. These Zones represent a reasonable restoration opportunity, given the severe canopy loss. Prior to Hurricane Michael portions of this area were either dominated by off-site pine or significantly fire suppressed (classified as successional hardwood forest) as indicated by 2016 aerial photography. Many hardwood trees fell in the storm and the majority of the remaining canopy is pine. Given the current heavy fuel loads, situated adjacent to a neighborhood, and considering the visibility of these areas near the entrance drive, a well-planned restoration effort, reducing the overall fuel loads and introducing longleaf and native desirable herbaceous groundcover species, would not only create a more aesthetic entrance to the park but also provide a properly defensible buffer to the wildland urban interface in the eastern corner of the park.

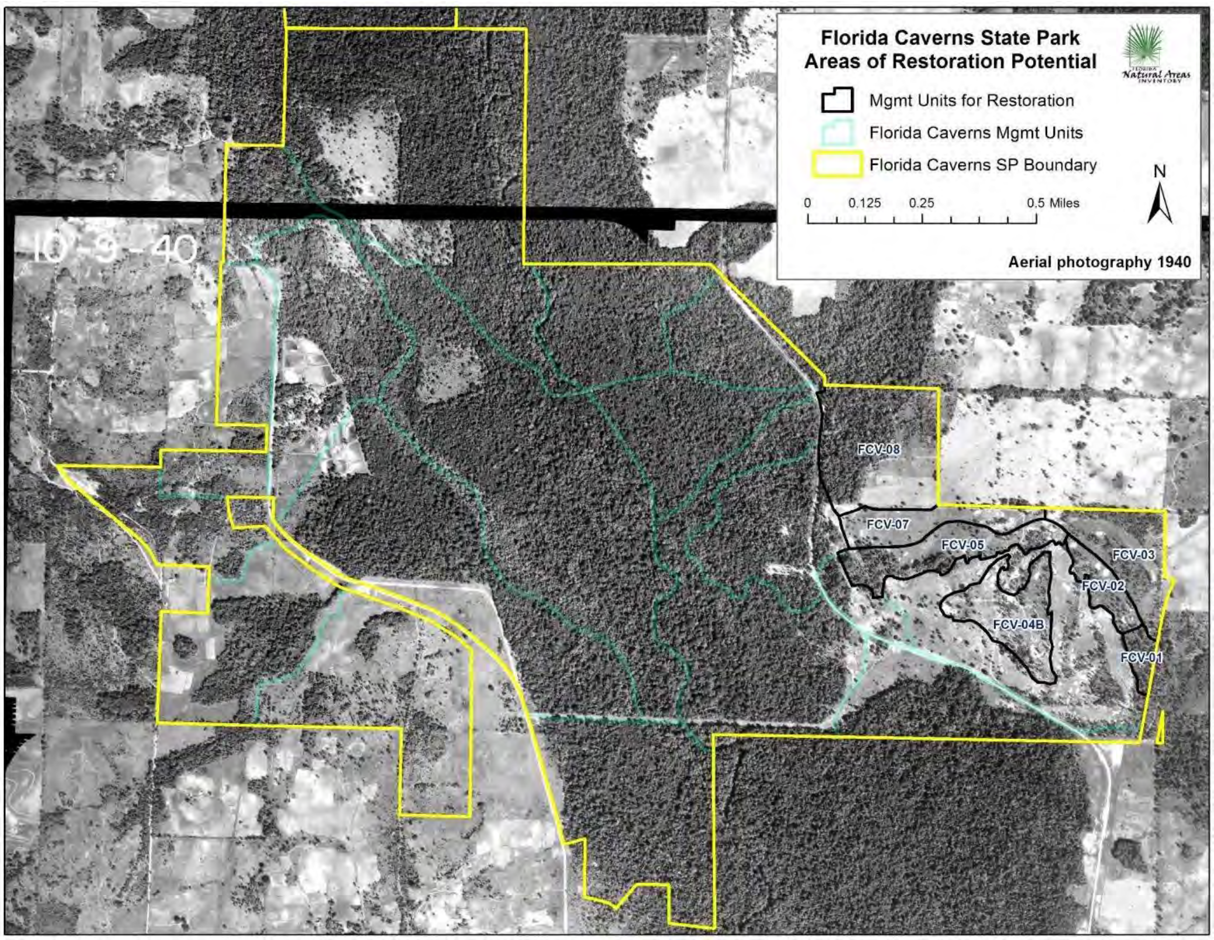

Figure 22. Florida Caverns State Park management units with 1940 aerial photography. Management units prioritized for restoration are highlighted.

Three Rivers State Park

Three Rivers State Park is a distinctive and unique assemblage of natural communities that truly adds diversity to the Florida State Park system. Located on rolling, red clay hills overlooking Lake Seminole and the confluence of the Chattahoochee and Flint River systems, the park offers spectacular vistas and natural features. The Park contains excellent examples of upland pine forests, one of Florida's least common natural communities. Additionally, dense slope forests include a diverse hardwood canopy of oaks, hickories, poplars, and a variety of rare plants, many reaching the southern extent of their habitat in extreme north Florida.

In the development of the most recent management plan (FDEP 2005), the potential of the park to accommodate secondary management purposes ("multiple uses") was analyzed. These secondary purposes were considered within the context of the Division's statutory responsibilities and an analysis of the resource needs and values of the park. This analysis considered the park natural and cultural resources, management needs, aesthetic values, visitation, and visitor experiences. The 2005 management plan determined that timber management (the limited selective removal of off-site pines for the sole purpose of habitat restoration) could be accommodated in a manner that would be compatible and not interfere with the primary purpose of resource-based outdoor recreation and conservation. It should be noted that while the site is managed by DEP, the Army Corps of Engineers in the property owner and dictates certain elements such as silvicultural actions. The long-term management goal for forest communities in the state park system is to maintain or re-establish old-growth characteristics to the degree practicable.

The Park provides habitat for many rare species, most notably gentian pinkroot (*Spigelia gentianoides*), a narrow endemic plant in the Family Loganiaceae. It was federally listed as an endangered species under the Endangered Species Act of 1973, as amended, on November 26, 1990 (55 FR 49046) and listed as endangered in the State of Florida under the Preservation of Native Plant Flora of Florida Act (Rule: 5B-40.0055, Section 581.185-187). The primary threats to gentian pinkroot are habitat loss and alteration. Factors contributing to these threats include clearcutting and/or selective thinning, mechanical site preparation, conversion of land to pine plantations, disruption of fire regimes, and permanent habitat loss through development (USFWS 2012). A significant population of this species is located at Three Rivers State Park (Table 3; USFWS 2009). The population was found to be ~2000 individuals in 2008, and less than 400 in 2010. A survey in 2011 estimated the population at 600-800 individuals (T. Spector, 2011, pers. comm., USFWS 2012). TRSP represents a significant proportion of the global population of this species, nearly 50%, and is essential to its recovery.

Task 1: Rapid Assessment of Timber Salvage Options

The rapid assessment is meant to consider all of the resources potentially affected by hurricane recovery operations using timber removal as the primary tool for site preparation. The first step is for natural resource managers to use the rapid restoration assessment matrix (RRAM) tool to estimate the effect of timber salvage operations on each of the 12 resources and to score those effects in four categories: 1) likely to adversely affect[2], 2) may affect, but not likely to adversely affect[1], 3) may benefit, but not likely

[2] Similar to, but not the same as the official determinations for Section 7 designations under the Endangered Species Act

to significantly benefit and 4) likely to benefit. Category 1 received a value of -2 (most negative), category 2 received a value of -1, category 3 was 1, and category 4 was 2 (most positive). Neutral or mixed positive and negative were rated 0.

First we ranked management units based on their total score, with the highest values representing the total number of positive benefits of treating a given unit. Because there is some uncertainty in the values and to test the sensitivity of the outcomes to the weight given to each element, we weighted natural resources related values, fire risk related values, and timber related values by multiplying these values by two. The top rated management units with the most positive benefits remained similar under these different weighting scenarios, inferring that the top units performed well across categories and were not subject to high degree of change depending on the weight of different values (Figure 23).

Based on the below analysis (Figures 23, 24 and Table 2), the units recommended to be considered for salvage operations were TH-E, TH-G, TH-F, TH-A, TH-H, TH-I and TH-B. We recommend no action for commercial timber for the remainder (33% of the total) of the units; although all areas near public use areas will need hazard tree reduction. Salvage harvest should continue along park roads and facilities where trees pose a hazard. The top sites had few impacts to natural and cultural resources, timber value and feasibility, and WUI and hazard mitigation benefits. Within the selected units where salvage may be appropriate, some areas still have adequate mature canopy, good stand structure, and only light to moderate damage therefore salvage is not required to meet DFCs. These sites are also possible or extant habitat for gentian pinkroot. For this reason, we are recommending minimum impact zones (see Figure 25). These polygons do not cover all the known locations, but do cover the areas were the species would not benefit from mechanical removal (i.e. the risks outweigh the benefits). Other gentian pinkroot sites are either within areas not recommended for treatment (Zone TH-C)), or areas where the damage is catastrophic to the degree that prescribed fire could not be safely implemented without sterilizing soils or the plants would be shaded by debris to the extent where removal in necessary to create the sunlight needed for persistence of the plant. No action sites were typically low lying areas which have infrequent disturbance. Table 2 provides scores for each resource that resulted in the final score.

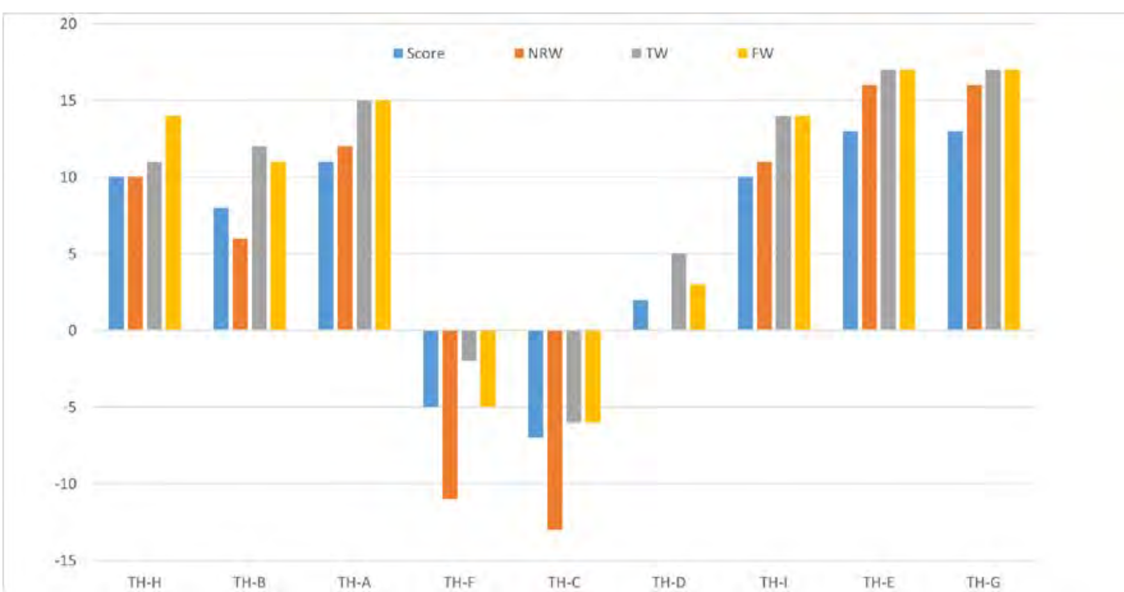

Figure 23. Total points by management unit based on rapid restoration assessment matrix tool. "Score" in blue has an equal weighting across values for all twelve factors. NRW = Natural resource weighted, TW=Timber elements weighted, FW =Fuels and fire risks weighted.

Table 2. Ranking table of scores for each resource with weighted values.

Table 2	Biotic Factors				Abiotic Factors											
ZONE_ID	NC	IS	So	SNF	MG	FS	TV	CR	LF	VE	FR	BAL	Score	NRW	TW	FW
TH-H	1	0	-1	0	1	0	1		2	2	2	2	10	10	11	14
TH-B	1	-2	-1	0	1	0	2		2	2	2	1	8	6	12	11
TH-A	2	0	-1	0	1	0	2		2	1	2	2	11	12	15	15
TH-F	-2	-2	-2	0	-1	0	2		1	-1	0	0	-5	-11	-2	-5
TH-C	-2	-2	-2	0	-1	0	2		-1	-2	1	0	-7	-13	-6	-6
TH-D	0	0	-2	0	0	0	2		1	0	1	0	2	0	5	3
TH-I	1	1	-1	0	1	0	2		2	0	2	2	10	11	14	14
TH-E	2	2	-1	0	2	0	2		2	0	2	2	13	16	17	17
TH-G	2	2	-1	0	2	0	2		2	0	2	2	13	16	17	17

NC= Natural Communities TV=Timber Value VE=Visitor Experience FR=Fire Risk NRW=Natural Resource Weighted
IS= Imperiled Species CR=Cultural Resources MG= Management Goals TW= Timber Elements Weighted
So=Soils LF=Logging Feasibility SNF= Special Natural Feature FW- Fuels and Fire Risk Weighted

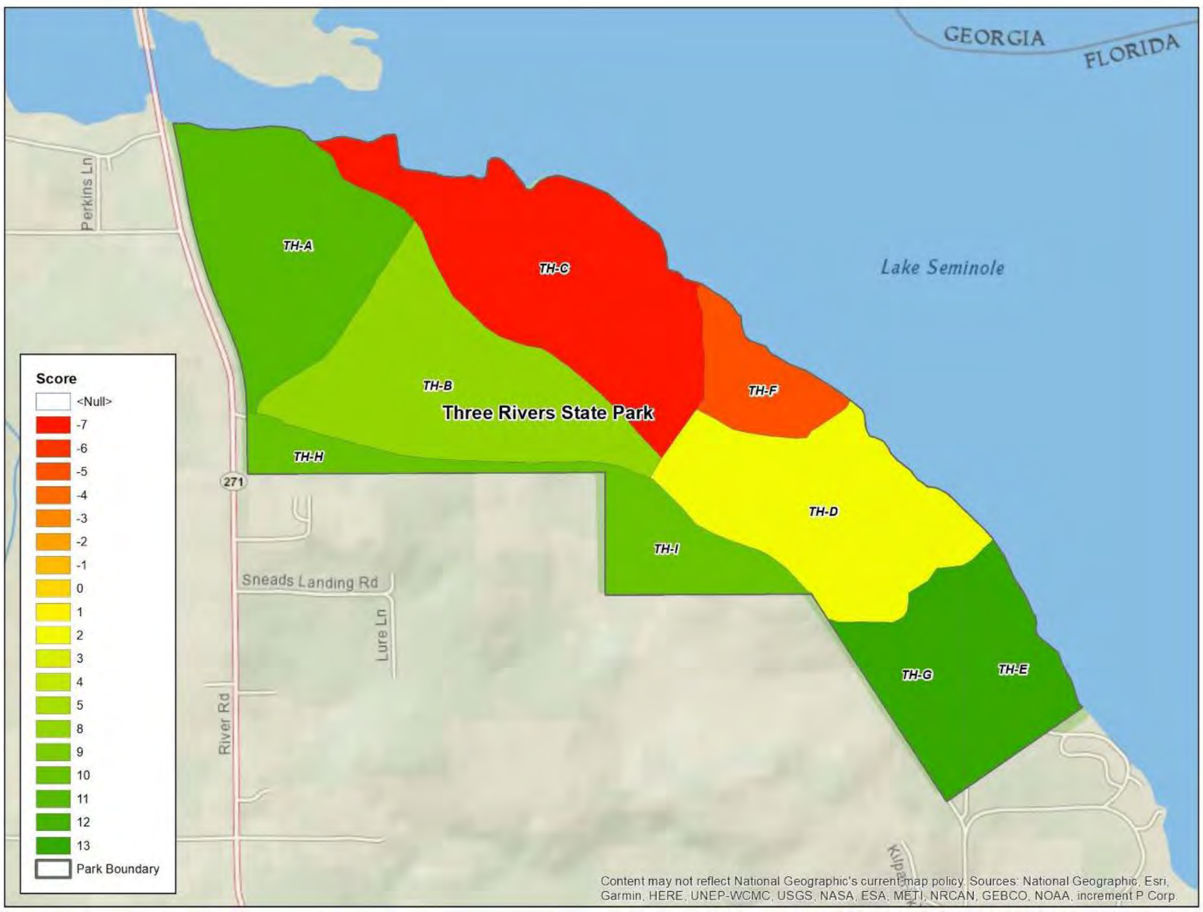

Figure 24. Unit Scores

Recommended Resource Protection Measures

Within the given units identified by the ranking and prioritization (TH-E, TH-G, TH-F, TH-A, TH-B, TH-H, and TH-I) where some level timber harvest could be conducted to attain DFCs (e.g. prepare sites for upland pine and groundcover restoration) and where expected positive outcomes outweigh negative consequences, the following practices should be implemented to reduce resource damage and increase the likelihood of long term restoration success where appropriate. The recommendations are for near term actions (less than 90 days as defined by the task agreement) and should be considered in addition to the standard DEP and Florida Department of Agriculture's BMPs for public lands timber harvest. The primary consideration is removal of trees and excessive fuels/hazard trees to prepare sites for restoration with the least possible soil disturbance.

1. Remove downed/>60% leaning merchantable and hazard timber from roadside, facilities, campsites, and fire breaks within 100 feet of the roadbed where possible.
2. Where timber is not accessible from roadside, use minimum impact techniques to reduce collateral damage to soil, groundcover, and live trees as recommended by logging operations specialists.
3. Consider using minimum impact techniques such as low ground pressure equipment such as dual-tire skidders, tracked machines or special techniques such as "mat-logging" or "shovel-logging" should be employed. Promptly remove the shovel-mat skid trail when no longer needed. If logs/trees are completely buried in the soil, then you may leave them in place to avoid further site disturbance. Do not excavate stumps or soil when installing or removing the shovel-mat skid trail.
4. Concentrate skid trails to as small an area as possible, and minimize the number of trails on a given site. Keep skid trails to 1 skidder wide. Minimize skidder and other rubber tired equipment operation to roads or skid trails.
5. Heavy equipment operations should be planned for dry seasons and/or dry periods only.
6. Clear fire breaks and access roads on the southern and western perimeter along units to serve as an alternate haul and working routes.
7. Flag and exclude operations near cultural resources sites within the recommended distance deemed appropriate by DEP cultural resources specialists.
8. Eagle nest protections: 1). avoid clear-cutting or removal of overstory trees within 330 feet (100 meters) of both active and alternate nests at any time. 2.) Avoid timber harvesting operations, including road construction and chain saw and yarding operations, during the nesting season within 660 feet (200 meters) of the nest. The distance may be decreased to 330 feet around alternate nests within a particular territory, including nests that were attended during the current nesting season but not used to raise young, after eggs laid in another nest within the territory have hatched. 3.) Selective thinning and other silviculture management practices designed to conserve or enhance habitat, including prescribed burning close to the nest tree, should be undertaken outside the nesting season or when eagles are not present.
9. a) Retain all live longleaf and shortleaf pines. Retain all pine trees and hardwoods greater than 25" DBH.

   b) Avoid harvesting damaged areas if safe operations require removal of trees as described in 5a.

10. Prohibit (or greatly reduce) heavy machinery (e.g. harvesters, skidders, feller bunchers, etc.) in high priority *Spigelia gentianoides* areas with light to moderate damage and fuels (Figure 25) except where pre-existing roads or fire breaks exist.
11. All machinery from offsite should be cleaned by high pressure to remove possible seed sources or introduction of exotics species.
12. Prevent erosion and protect soils from compaction and rutting.
13. Leave scattered non-merchantable medium and large logs. Avoid exposing soils by completely removing litter and debris.

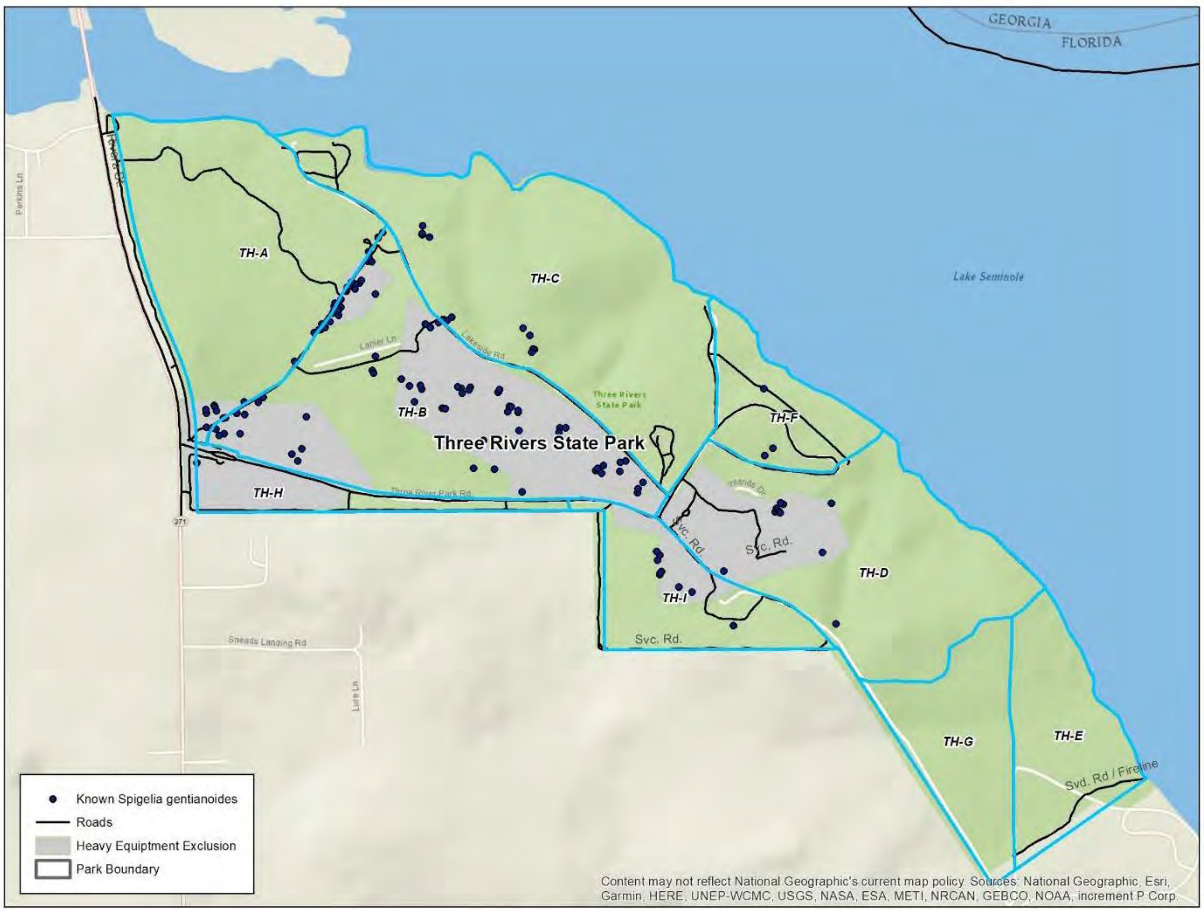

Figure 25. Recommended heavy equipment exclusion/reduction zones.

Task 2: Rapid Damage Assessment

Rapid damage assessment was conducted at two scales: using remote sensing and on the ground with plots and visual observations. First, damage was assessed through remote sensing using normalized difference vegetation index (NDVI). NDVI is a simple graphical indicator that assesses whether the target being observed contains live green vegetation; this has been used effectively to assess storm damage (Wang et al. 2010). Using MODIS satellite imagery, FNAI determined the difference in NDVI (dNDVI) from October 2017 to October 2018 (Figure 26) and then applied the values to natural communities and park boundaries (Figure 27). MODIS satellite imagery provides NDVI values at a 250x250 meter scale. Some factors which need to be considered when interpreting NDVI readings are: 1) areas dominated by grass, standing water, or impervious surface may alter results; 2) other landuse changes within the last year (e.g. fire, logging, etc.); 3) actual damage to deciduous trees could be overestimated and 4) trees, especially pines, may not have fully browned. Next, dNDVI values were assigned to damage class bins which were created using post storm imagery and U.S. Forest Service hurricane fuels assessment categories (Figure 27).

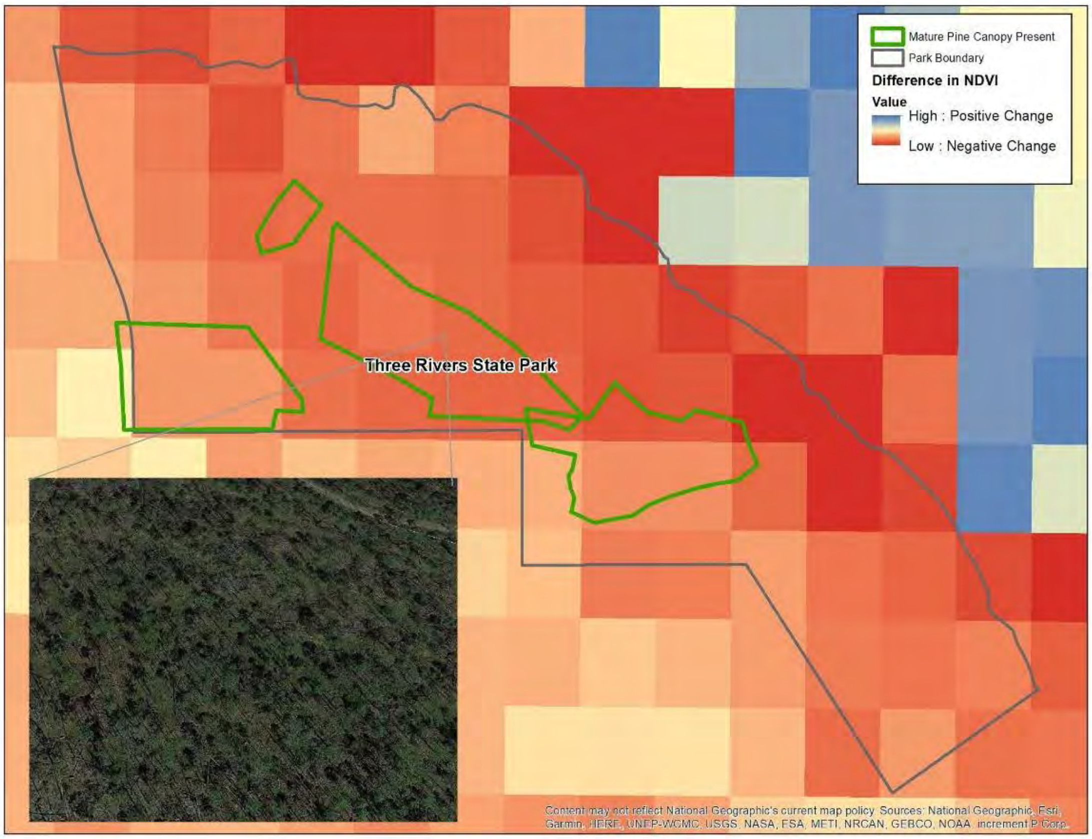

Figure 26. dNDVI estimated damage with ground/post-storm imagery mapping of mature pine stands (green polygons).

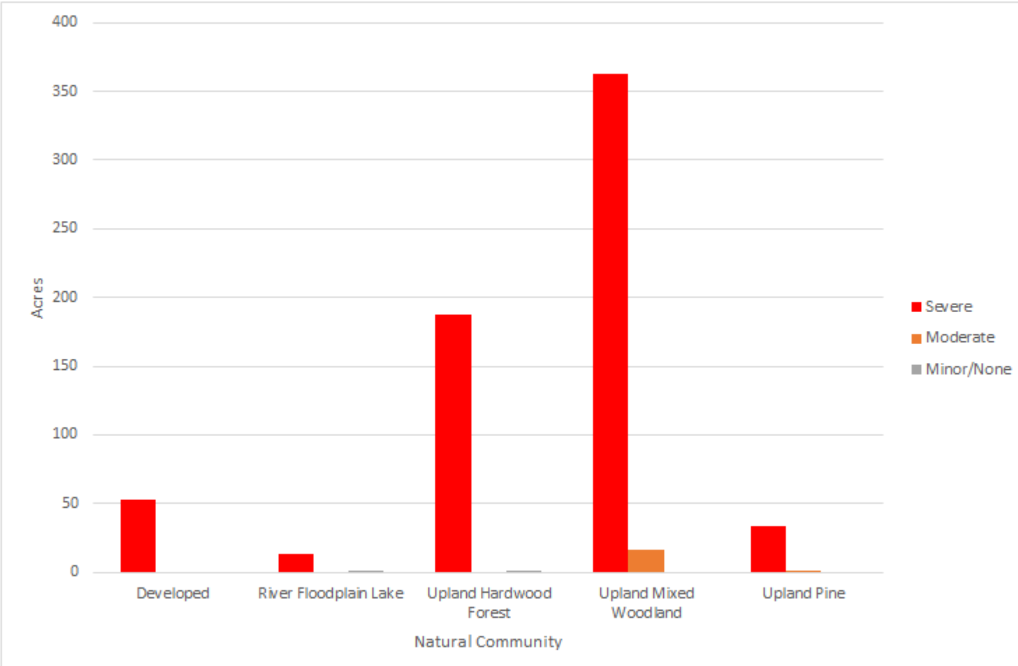

Figure 27. dNDVI Estimated Acres by Damage Class

A field assessment was completed on December 13, 2018 and February 11, 2019. FNAI scientists surveyed accessible areas on foot and vehicle to evaluate aspects of the habitat conditions that cannot be observed via aerial photography. We estimated fuels and other forest structure metrics (Figures 28 and 29) using standard FNAI natural community plots (see Appendix H for data form and category definitions) with photo points collected at the center of each plot (See Appendix B). Because access and time was limited, we conducted non-random assessment plots. The number of plots was determined by the range of variability found within each natural community represented. We also limited the scope of our on the ground assessments to natural communities which would have higher restoration potential (e.g. where active management is generally more appropriate).

Canopy loss was variable, from light to severe in plots, with the overall damaged and downed trees averaging 60% across all plots. The most notable changes from the storm are in the form of heavy fuel loads of downed trees as well as increased sunlight to the surface. Both of these factors will drive changes in the plant composition and structure of the understory flora. The canopy damage was variable across the park, ranging from 31-91% in plots. Many of the upland pine sites had more moderate (~50%) damage allowing a fairly natural pine stand remaining. In our plots, an average of 64% of mature trees (>7” dbh) were down (Figure 28). Upland glade and mixed hardwood seemed to have the greatest number of trees down, 91% and 73% respectively, and upland pine and upland mixed hardwood seemed to have the least effects with average downed trees per plot near 50% for each. The damage includes entirely blown down trees (exposing the root balls) as well as broken main stems (forming “A frames”).

Light, medium, and heavy fuels were high, on average, in all plots, averaging 2.6 (midway between moderate and high) on a scale of 1 to 3. Litter cover was relatively low, at about 45%. Post storm canopy cover was only 10.6% in all plots on average, but this was possibly a result of the additive effect of normal winter senescence and hurricane effects in some cases. Upland pine had the highest remaining canopy cover with an average of about 15%. Upland glade had the lowest canopy cover (0%) post storm; however, data was only collected in one upland glade plot as that community comprises a very small acreage in the park. Canopy cover was also low in mixed woodland and upland hardwood at 3% and 8% respectively. Basal area and graminoid cover contributed most to the differences among plots. (Figure 25).

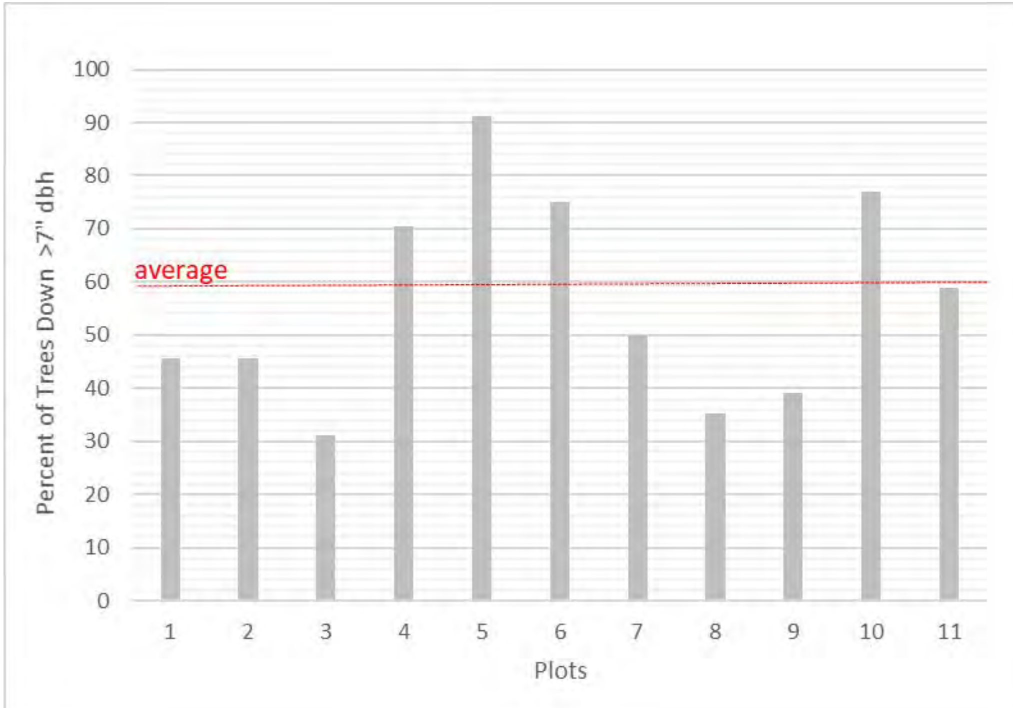

Figure 28. Percent of trees (>7" dbh) down in each plot.

Natural Community	Canopy Height	Canopy Cover	Subcanopy Height	Subcanopy Cover	Pine Basal Area
upland hardwood forest	80.0	2.5	22.5	10.5	0.0
upland mixed woodland	69.0	7.3	37.5	2.1	36.0
upland pine	61.7	8.3	24.0	2.6	11.7
Average	**64.7**	**7.7**	**25.0**	**2.9**	**17.8**
	Fine Fuels	**Medium Fuels**	**Heavy Fuels**	**Graminoid Cover**	**Total Shrub Cover**
upland hardwood forest	3.0	3.0	3.0	40.5	2.5
upland mixed woodland	3.0	3.0	3.0	17.3	8.7
upland pine	2.6	2.8	2.8	10.7	8.1
Average	**2.7**	**2.8**	**2.8**	**14.2**	**8.0**

Figure 29. Average values for each community type surveyed. Data summary of plots. . Height measurements in feet, cover in percentages, pine basal area in ft^2/acre. For fuels low is 1, moderate, is 2, and 3 is high relative to DFCs.

At the time of the field assessment, tree removal was underway at the park, focusing on the immediate needs of clearing trees on and hanging over roads, structures, and staff safety areas (e.g. picnic areas and campgrounds). The entrance to the park was an early priority because of the access to the park for visitors and the structural dangers to park infrastructure. Most of the timber that had impacted the paved road system through the park has been removed from the roadways and large tree trunks stacked

(Figure 30) at time of our survey. Blue stain was observed in some of these stacks on December 13 (Figure 31).

Figure 30. Stacked timber near the park campground entrance.

Figure 31. Stacked pine logs showing blue stain.

The areas near the campground and picnic areas are mostly cleared of large trees following the work that has already been completed (Figures 32 and 33). These places, given their visibility to the public, may be early restoration priorities.

Figure 32. Campground during active cleanup of downed trees.

Figure 33. Day-use area at Three Rivers State Park after damaged tree removal.

Longleaf pine habitats

Longleaf pine habitats at TRSP include upland pine and upland mixed woodland. Both of these habitats historically have an open canopy of longleaf pine (*Pinus palustris*) and in the less common upland mixed woodland a mixture of hardwoods (i.e., red oak, flowering dogwood, mockernut hickory) would also be present. Both habitats require fire (suggested fire return interval (FRI) 1-3 years for upland pine and variable 2-20 years for upland mixed woodland) to maintain their open community structure with a variable herbaceous understory (FNAI 2010). Most of the park was historically dominated by these pine uplands in a mosaic where upland pine occupies the highest elevations and upland mixed woodland tends to occupy the lower slopes and is often adjacent to the slope forests. Canopy damage was observed in all areas we visited, with varying degrees of severity (30-80% in plots). The pine uplands represent the most feasible portions of the park for pine salvage removal in terms of potential to move towards DFCs. Several areas such as portions of Zone TH-B, TH-H, portions of TH-A, TH-I, and TH-D suffered only light to moderate canopy damage, the remaining trees are majority longleaf pine (*Pinus palustris*), and remain as fairly natural stand structure (Figures 34 and 35) with intact herbaceous groundcover. Reintroducing fire as soon as feasible in these areas will be important to reduce fuels and aid the recovery of the ground cover.

Figure 34. Zone TH-H along the entrance drive. The canopy damage to this area is moderate and remaining is still a majority longleaf pine canopy is near desired future conditions as far as canopy cover and basal area.

Figure 35. Upland pine in Zone TH-I where you can see variable tree loss with severe canopy damage in the left of the photo and moderate to light damage in the right.

The only area of significant wiregrass (*Aristida stricta*) cover seen during the field assessment is in a portion of the upland pine in Zone TH-I. The canopy over this wiregrass only suffered moderate damage

(Figure 36). Minimizing equipment impacts to the groundcover and returning fire would be the most efficient method to restoring desired future conditions.

Figure 36. Notable wiregrass cover in an area of moderate hurricane canopy damage in Zone TH-I.

The increased sunlight resulting from the canopy damage may be a long-term benefit to groundcover in some stands (particularly those highlighted in the mechanical restriction zones, Figure 37) at TRSP where fire exclusion has resulted in hardwood invasion of the canopy and shrub layers. A good example of this is in a portion of Zone TH-A where vines such as muscadine (*Vitis rotundifolia*) and earleaf greenbrier (*Smilax auriculata*) are common, shrubs cover is greater than desirable and is made up of weedy species such as winged sumac (*Rhus copallinum*), and laurel oak (*Quercus hemisphaerica*), and herbaceous species only make up a minor component of the groundcover (Figure 37). Places such as this are good opportunities for restoration (longleaf and/or desirable herbaceous species planting) once the increased fuel loads (downed trees) have been addressed. These areas represent the best opportunity for salvage logging to contribute to long-term restoration.

Figure 37. Portion of Zone TH-A with severe canopy damage and heavily invaded with vines and shrubs. This area is an excellent candidate for restoration efforts.

All populations of gentian pinkroot were likely impacted by Hurricane Michael. In our survey it appeared that the areas of the park where gentian pinkroot is located suffered less canopy damage than other parts of the park. Several individuals were observed during the field visit (Figure 38). This could be attributed to increased fire being applied to the zones to benefit this species in the past. However, there are definitely heavy fuels and debris through the habitat of this species that may impede fire in the immediate future. Intensive surveys for gentian pinkroot should take place in May 2019 to assess the population post-storm.

Figure 38. Flags remaining at gentian pinkroot locations from a previous survey (before the storm). One plant was observed at the nearest flag in the photo during the field visit on December 13, 2018.

Upland Hardwood Forest/Upland Glade

In closed canopied habitats such as upland hardwood forest (see FNAI 2010), the increased sunlight resulting from tree damage will drastically change the understory microclimate. The successional changes that will occur over the next 20-50 years in each of these habitats is unknown. Early successional species, such as laurel cherry (*Prunus caroliniana*), and invasive species, such as Japanese climbing fern (*Lygodium japonicum*) or Chinese privet (*Ligustrum sinense*), may show dramatic increases in the immediate future. Community structure and composition monitoring would allow us to document and better understand these successional transitions.

Significant canopy damage occurred in the upland hardwood forests at TRSP (Figure 39). These are mixed canopy forests dominated by a diverse suite of species including deciduous trees such as white oak (*Quercus alba*), Florida maple (*Acer saccharum* ssp. *floridanum*), and American beech (*Fagus grandifolia*), and evergreen species such as southern magnolia (*Magnolia grandiflora*), live oak (*Quercus virginiana*) and spruce pine (*Pinus glabra*). The dense canopy of upland hardwood forests and multiple layers of midstory vegetation restrict air movement and light penetration, which maintains high relative humidity within this community. The groundcover is made up of shade-tolerant herbs, graminoids, and vines, several of which are rare in Florida and more common further north (i.e., Carolina lily (*Lilium michauxii*)). Given the significant canopy loss due to Hurricane Michael, the delicate microclimate of these areas will undoubtedly be changed causing unknown effects to the community structure and composition that will need to be evaluated through monitoring of vegetation changes. A concern of note is how the fragile spring ephemerals such as wakerobin (*Trillium* sp.) in the ground layer of this habitat at TRSP will respond to the change in light availability.

In order to maintain the rich soil layer present in upland hardwood forests, leaving as much debris and logs on the forest floor as possible (as opposed to removing it from the site) will help achieve desired future conditions (except in areas where trees removal is necessary for safety concerns). This will help prevent erosion in these sloping forests and help build the nutrient-rich soil back up, not only by decomposing themselves but serving to catch falling leaves and hold them in place. Several rare plant species occur in the upland hardwood forest (Figure 39) at TRSP including but not limited to bay star-vine (*Schisandra glabra*), Baldwyn's spiny-pod (*Matelea baldwyniana*), and green adder's-mouth orchid (*Malaxis unifolia*). All of these populations should be revisited when it is phenologically appropriate to evaluate the populations post hurricane.

Figure 39. Rich upland hardwood forest adjacent to Lake Seminole in southwest portion Zone TH-C.

The most sensitive habitat at TRSP is upland glade. Upland glades are mostly herbaceous communities on thin soils over limestone outcrops on steep topography. They occur as small openings in an otherwise forested landscape. Additionally, the upland glade at TRSP is home to a small number of the federally-listed gentian pinkroot, making this an even more important area to conserve. This area was visited during the field assessment had severe damage from the hurricane in the form of tree loss (Figure 40). With the highly sensitive nature of the soil in upland glades, any further soil disturbance is discouraged, especially heavy equipment disturbance. Careful hand clearing of this very small area would be ideal if it is determined that some of the debris is detrimental to this fragile habitat. Several other rare plant species occur in the glade at TRSP including eastern purple coneflower (*Echinacea purpurea*) and poppy mallow (*Callirhoe papaver*). All of these populations should be revisited when it is phenologically appropriate to evaluate the populations post hurricane.

Figure 40. Upland glade at TRSP with blue flags showing where gentian pinkroot plants were found in a previous survey. One plant was observed here during this survey.

Task 3: Restoration Evaluation

For those areas of the park not being considered for hurricane restoration by timber removal, options to consider include: prescribed burning, native planting, native seeding, mechanical removal of vegetation, and chemical control of exotic species (could be conducted in all areas with hazard tree removal). In this document we outlined actions that can be taken in the near term (within 90 days). Many additional actions, such as groundcover restoration and pine planting, will likely occur outside of the near term. This document outlines only the types of actions needed to facilitate the planning and future success of longer- term restoration activities (post 90 days). Near term actions will mainly consist of preparing a site for restoration (e.g. timber or brush removal), except in portions of that have already been cleared.

Recommendations Based on Historic and Current Conditions

Upland pine sites with mature canopies and scattered to light damage should be left to recover without mechanical disturbance. Mature longleaf and shortleaf pine are still present to the degree that replanting should not be necessary in the heavy equipment exclusion zones. In these cases, prescribed fire and small crew work to clear firelines is recommended. Conservation of these areas will serve as an anchor point for future restorations in heavily damaged zones such as A, G, and E.

The sites that have been determined appropriate for timber removal are also the best suited for continued restoration actions (TH-E, TH-G, TH-F, TH-A, TH-B, TH-H, and TH-I; see also Table 2, Figure 24).

These areas have extensive damage that will prohibit introduction of fire, exotics control, and other forms of management. Therefore, action is needed. These areas were generally further departed from DFCs pre-storm, with high canopy cover, thick shrubs and vines, and limited occurrences of rare plants. The damage resulting from Hurricane Michael created some opportunities for restoration of habitats that were already somewhat degraded due to insufficient fire and past land use history. While these areas will succeed naturally from the storm with no action, the current situation provides an opportunity to attain DFCs.

Aerial photography from 1940 indicates that most of the park was historically a pine dominated community, likely upland pine in higher areas and upland mixed woodland on lower slopes (Figure 41). The extreme southeastern section (Zones TH-G and TH-E) were cleared for agriculture as early as 1940. These zones represent a reasonable restoration opportunity, given the significant canopy loss. Many of the hardwoods fell in the storm and the majority of the remaining canopy is pine. Given the current situation of extremely heavy fuel loads, a well-planned restoration effort, reducing the overall fuel loads and introducing longleaf and native desirable herbaceous groundcover species would benefit these areas.

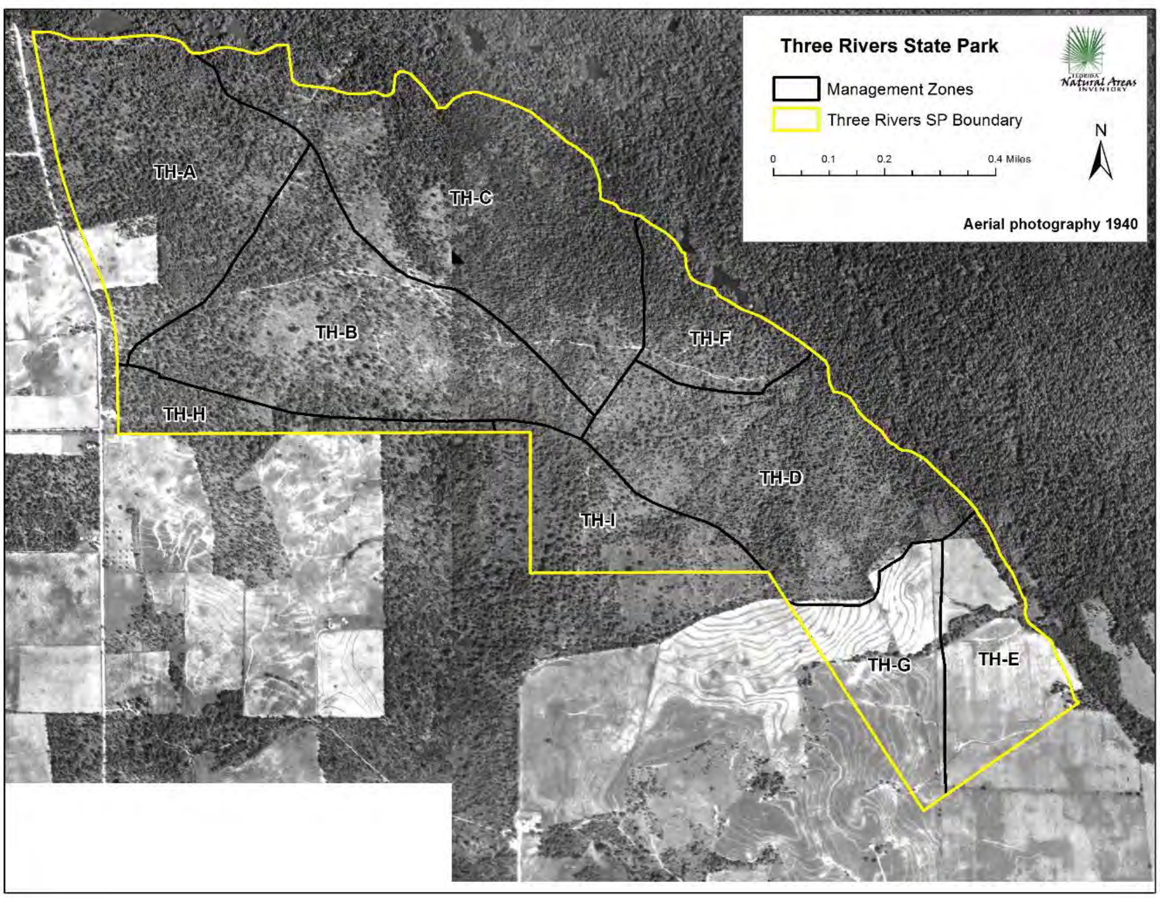

Figure 41. Three Rivers State Park management units with 1940 aerial photography.

Torreya State Park

Management Context Related to Restoration Activities

Torreya State Park (TSP) plays a critical role in preserving unique plant and animal species and natural communities that are of regional importance, and protecting the water quality of the Apalachicola River, which feeds the productive Apalachicola Bay. The park's high plateaus, steep bluffs and deep ravines are covered with rich forests that harbor a variety of rare and endemic plants and animals, many of which are more common further north than this location. In the management of a state park, a balance is sought between the goals of maintaining and enhancing natural conditions and providing various recreational opportunities. Natural resource management activities are aimed at management of natural systems. The park's primary management goals are:

1. Provide administrative support for all park functions.
2. Protect water quality and quantity in the park, restore hydrology to the extent feasible and maintain the restored condition.
3. Restore and maintain the natural communities/habitats of the park.
4. Maintain, improve or restore imperiled species populations and habitats in the park.
5. Remove exotic and invasive plants and animals from the park and conduct needed maintenance-control.
6. Protect, preserve and maintain the cultural resources of the park.
7. Provide public access and recreational opportunities in the park.
8. Develop and maintain the capital facilities and infrastructure necessary to meet the goals and objectives of this management plan.

In the 2012 management plan secondary purposes, such as timber management, were considered within the context of DRP's statutory responsibilities and the resource needs and values (natural and cultural resources, management needs, aesthetic values, and visitation and visitor experiences). For TSP, it was determined that timber management activities for restoration could be accommodated in a manner that would be compatible and not interfere with the primary purpose of resource-based outdoor recreation and conservation.

Similarly to pre-storm management activities, perpetuation of the vast majority of rare plants, animals, and natural communities can be accomplished post-storm by "passive" management activities afforded by inclusion within the park boundary -- protection from poaching, protection from over-collection, and preservation of habitats. However, several species and natural communities such as gopher tortoises and sandhill, require active management efforts such as prescribed burning. Without some level of hurricane recovery action (e.g. storm debris and/or downed timber removal) post storm, prescribed burning could be challenging to implement and the overall management goals and desired future conditions may be difficult to obtain.

Several of the rare plant species in the park are either directly or indirectly dependent on frequent fire for their continued existence and benefit from prescribed burning. Such species that occur in upland pine include Apalachicola wild indigo and toothed savory. It is also very likely that long-term reproductive success of several plant species in the park, such as Florida spinypod, Florida mountain mint, and orange azalea, depend on maintaining ecotonal areas between upland pine and slope forests/ upland hardwood forests. For example, in northern states, research has shown that fire plays a role in maintenance of stands of mountain laurel.

Task 1: Rapid Assessment of Timber Salvage Options

The rapid assessment is meant to consider all of the resources potentially affected by hurricane recovery operations using timber removal as the primary tool for site preparation. The first step is for natural resource managers to use the rapid restoration assessment matrix (RRAM) tool to estimate the effect of timber salvage operations on each of the 12 resources and to score those effects in four categories: 1) likely to adversely affect[3], 2) may affect, but not likely to adversely affect[1], 3) may benefit, but not likely to significantly benefit and 4) likely to benefit. Category 1 received a value of -2 (most negative), category 2 received a value of -1, category 3 was 1, and category 4 was 2 (most positive). Neutral or mixed positive and negative were rated 0.

Because of the large number of units where active restoration would not be feasible (e.g. floodplain, slope forest) and those already included in other restoration efforts (Sweetwater tracts) we limited our review to those units which had at least 50 acres of upland pine or sandhill and were not in the Sweetwater restoration area. After that, we ranked management units based on their total RRAM score, with the highest values representing the highest number of positive benefits of treating a given unit. Because there is some uncertainty in the values and to test the sensitivity of the outcomes to the weight given to each element, we weighted natural resources related values, fire risk related values, and timber related values by multiplying these values by two. The top rated management units with the most positive benefits remained similar under these different weighting scenarios, inferring that the top units performed well across categories and were not subject to high degree of change depending on the weight of different values (Figure 42).

The units recommended to be considered for salvage operations were those with the high overall average score: TY-F, TY-A04, TY-E1, TY-A29, TY-A15, and TY-H. Although other units scored similarly which could be considered (see Figures 42, 43, and Table 3 below). Areas which scored highest were far departed from DFCs and were generally comprised of former plantations. These had few resources of concern and had higher fire risk and fire management benefits by protecting adjacent private land in the WUI. We recommend no action for commercial timber for the remainder of the units; although all areas near public use facilities will need hazard tree reduction. Salvage harvest should continue along park roads and facilities where trees pose a hazard. The top RRAM scoring sites are anticipated to have had few impacts to natural timber value, and WUI and hazard mitigation benefits[4]as a result of salvage operations.

Not all units are homogenous and may contain a mix of natural and planted stands. Within natural stands, some areas have high quality groundcover that should be protected to avoid long term impacts

[3] Similar to, but not the same as the official determinations for Section 7 designations under the Endangered Species Act

[4] Cultural resources should be considered, but we did have the information available in the management plan as with other units. Cultural experts should review final unit prescriptions.

from the reduction in diversity and fuel continuity. For this reason, we are recommending minimum impact zones (see Figure 52). These polygons do not cover all areas with wiregrass and other desirable cover, but do cover the significant known areas. We recommend entering an area of intact groundcover only if the damage is catastrophic to the degree that prescribed fire could not be implemented. However, selective tree removal could likely be conducted with minimum damage in plantation areas with light damage and with no or some desirable ground cover elements consider variable thinning to (target average of 40, with variability 20-70 sq. ft/acre) to improve habitat quality in the long term and reduce short-term impacts.

If operational ease is desired, a “row plus mark” thinning is recommended. In this case, the pine stand is marked with paint (one mark at 5-6 feet and a second mark at ground line with all markings facing the same direction for the logger’s sake) on each “leave” (good tree not to be harvested with no visible defect) or each “take” (tree to be harvested, trees with a visible defect or low canopy position, small diameter trees that will not respond to a thinning) tree. A reputable, professional forester or person with years of experience and a good reputation is desired for this task. First, every 3rd, 4th, or 5th (sometimes every 6th or 7th row in rare cases) row is harvested, then the cut-down machine operator. On his second pass, the logger cuts down all trees that are marked as “take” trees or cuts all unmarked trees, leaving all trees that are marked as “leave” trees as specified (Dickens 2015).

Figure 42. Total points by management unit based on rapid restoration assessment matrix tool. "Score" in blue has an equal weighting across values for all twelve factors. NRW = Natural resource weighted, TW=Timber elements weighted, FW =Fuels and fire risks weighted.

Table 3. *Ranking table of scores for each resource with weighted values.*

	Biotic Factors				Abiotic Factors											
ZONE_ID	NC	IS	So	SNF	MG	FS	TV	CR	LF	VE	FR	BAL	Score	NRW	TW	FW
TY-A	-1	0	-1	-1	0	-1	0		2	-2	1	1	-2	-5	0	0
TY-F	1	1	-1	0	1	0	1		2	1	1	2	9	10	12	12
TY-A01	-2	0	-1	0	-1	0	2		1	0	0	1	0	-3	3	1
TY-A06	-2	0	-2	0	1	0	1		1	0	0	0	-1	-5	1	-1
TY-J	-1	0	-2	0	1	0	1		1	0	1	1	2	-1	4	4
TY-A05	-1	0	-2	0	1	0	1		1	0	0	0	0	-3	2	0
TY-A17	-1	0	-1	0	-1	0	1		1	0	1	1	1	-1	3	3
TY-A14	-1	0	-1	0	-1	0	1		1	0	1	1	1	-1	3	3
TY-A15	1	0	-1	0	1	0	1		1	0	1	1	5	5	7	7
TY-B	0	-1	-2	0	0	-1	2		2	0	2	0	2	-1	6	4
TY-A08	0	0	-1	0	-1	0	1		1	0	0	1	1	0	3	2
TY-A02	-2	0	-2	0	-1	0	2		1	0	0	0	-2	-6	1	-2
TY-E1	1	1	-1	0	1	0	0		2	0	1	1	6	7	8	8
TY-A04	1	0	-1	0	1	0	1		1	0	2	2	7	7	9	11
TY-G	-1	0	-1	0	0	0	2		1	0	1	2	4	2	7	7
TY-L	-2	-1	-2	0	-1	0	1		-1	0	0	1	-5	-10	-5	-4
TY-K	-2	-1	-2	0	-1	0	1		-1	0	0	1	-5	-10	-5	-4
TY-T	-2	-1	-2	0	-1	0	1		-1	0	0	0	-6	-11	-6	-6
TY-C	-2	-1	-2	0	-1	0	1		-1	0	0	1	-5	-10	-5	-4
TY-H	0	0	-1	0	1	0	1		2	0	1	1	5	4	8	7
TY-U	-2	-1	-2	0	-1	0	1		-1	0	0	1	-5	-10	-5	-4
TY-A26	1	0	-1	0	-1	0	1		-1	0	0	1	0	0	0	1
TY-A18	-1	0	-1	0	1	0	1		1	0	1	2	4	2	6	7
TY-D	-1	0	-2	0	-1	-1	1		1	-2	1	1	-3	-6	-1	-1
TY-A07	0	0	-1	0	-1	0	1		1	0	0	1	1	0	3	2
TY-A21	-2	0	-2	0	-1	0	1		-1	0	1	2	-2	-6	-2	1
TY-I	-1	0	-1	0	0	0	1		1	0	1	2	3	1	5	6
TY-O	-1	0	-1	0	0	0	1		-1	0	1	2	1	-1	1	4
TY-M	-1	0	-1	0	0	0	1		1	0	1	2	3	1	5	6
TY-Z	-1	-1	-2	0	-1	-1	2		1	-1	2	0	-2	-6	1	0
TY-A30	1	0	-1	0	1	0	1		1	0	1	1	5	5	8	10
TY-A31	1	0	-2	0	1	0	1		1	0	2	2	6	5	7	7
TY-A29	1	0	-1	0	1	0	1		1	0	1	1	5	2	5	5
TY-A13	0	0	-1	0	0	0	1		1	0	1	1	3	0	0	0

NC= Natural Communities
IS= Imperiled Species
So=Soils
TV=Timber Value
CR=Cultural Resources
LF=Logging Feasibility
VE=Visitor Experience
MG= Management Goals
SNF= Special Natural Feature
FR=Fire Risk
NRW=Natural Resource Weighted
TW= Timber Elements Weighted
FW- Fuels and Fire Risk Weighted

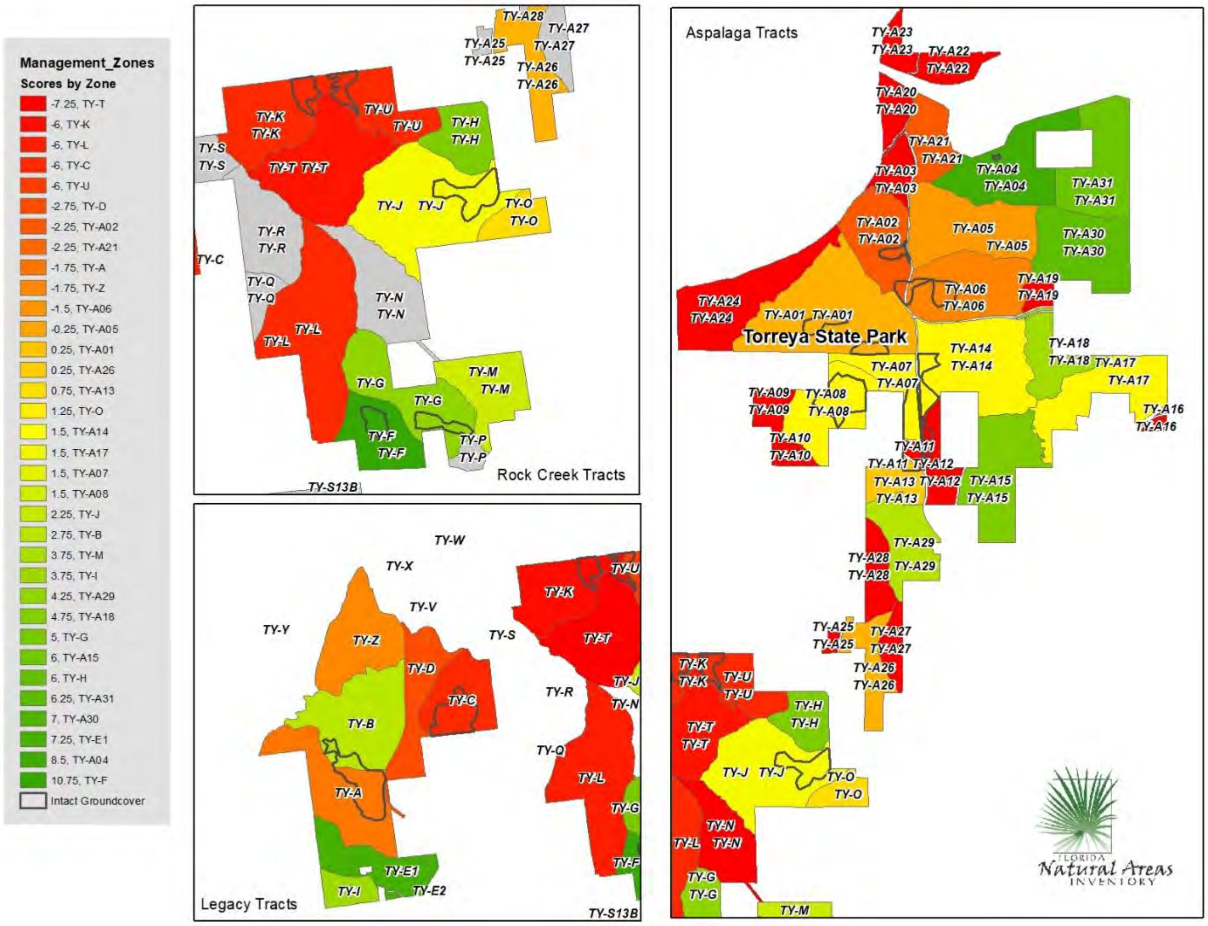

Figure 43. Average overall score for units, with green having the relative highest scores relative to other units. Units that scored high had high need for restoration, fire management benefits, and few negative resource impacts.

Recommended Resource Protection Measures

Within the given units identified by the ranking and prioritization (TY-F, TY-A04, TY-E1, TY-A29, TY-A15, and TY-H) where some level timber harvest could be conducted to attain DFCs (e.g. prepare sites for upland pine/sandhill and groundcover restoration) where expected positive outcomes outweigh negative consequences, the following best management practices are recommended to reduce resource damage and increase the likelihood of long term restoration success towards to DFCs. The recommendations are for near term actions (less than 90 days as defined by the task agreement) and should be considered in addition to the standard DEP and Florida Department of Agriculture's BMPs for public lands timber harvest. The primary consideration would be removal of trees and excessive fuels/hazard trees to prepare sites for restoration with the least possible soil disturbance.

1. Remove downed/>60% leaning merchantable and hazard timber from roadside, facilities, campsites, and fire breaks within 100 feet of the roadbed where possible.

2. Where timber is not accessible from roadside, use minimum impact techniques to reduce collateral damage to soil, groundcover, and live trees as recommended by logging operations specialists.
3. Use low ground pressure equipment such as dual-tire skidders, tracked machines or special techniques such as “mat-logging” or “shovel-logging” should be employed. Promptly remove the shovel-mat skid trail when no longer needed. If logs/trees are completely buried in the soil, then you may leave them in place to avoid further site disturbance. Do not excavate stumps or soil when installing or removing the shovel-mat skid trail.
4. Concentrate skid trails to as small an area as possible, and minimize the number of trails on a given site. Keep skid trails to 1 skidder wide.
5. Minimize skidder and other rubber tired equipment operation to roads or skid trails.
6. Heavy equipment operations should be planned for dry seasons and/or dry periods only.
7. Clear fire breaks on perimeters to serve as an alternate haul and working route.
8. Flag and exclude operations near cultural resources sites within the recommended distance deemed appropriate by DEP cultural resources specialists.
9. a) Retain all live longleaf and shortleaf pines. Retain all pine trees and hardwoods greater than 25” DBH.

   b) Avoid harvesting damaged areas if safe operations require removal of trees as described in 5a.
10. Flag and avoid significant groundcover areas (Figure 52) to the extent possible.
11. All machinery from off site should be cleaned by high pressure washing to remove possible seed sources or introduction of exotics species.
12. All hazard trees should be dropped and left on site if determined to be non-merchantable.
13. In plantations consider thinning by either row plus mark thinning or variable density thinning (standing and down) of plantations to 20-70 ft^2/ac (target average 40) to improve forest health and aid in restoration to DFCs.
14. Prevent erosion and protect soils from compaction and rutting.
15. Leave scattered non-merchantable medium and large logs. Avoid exposing soils by completely removing litter and debris.

Task 2: Rapid Damage Assessment

Rapid damage assessment was conducted at two scales: using remote sensing and on the ground with plots and visual observations. First, damage was assessed through remote sensing using normalized difference vegetation index (NDVI). NDVI is a simple graphical indicator that assesses whether the target being observed contains live green vegetation; this has been used effectively to assess storm damage (Wang et al. 2010). Using MODIS satellite imagery, FNAI determined the difference in NDVI (dNDVI) from October 2017 to October 2018 (Figure 44) and then applied the values to natural communities and park boundaries MODIS satellite imagery provides NDVI values at a 250x250 meter scale. Some factors which need to be considered when interpreting NDVI readings are: 1) areas dominated by grass, standing water, or impervious surface may alter results; 2) other land use changes within the last year (e.g. fire, logging, etc.); 3) actual damage to deciduous trees could be overestimated and 4) trees, especially pines, may not have fully browned. Next, dNDVI values were assigned to damage class bins which were created using post storm imagery and U.S. Forest Service hurricane fuels assessment categories (Figure 45).

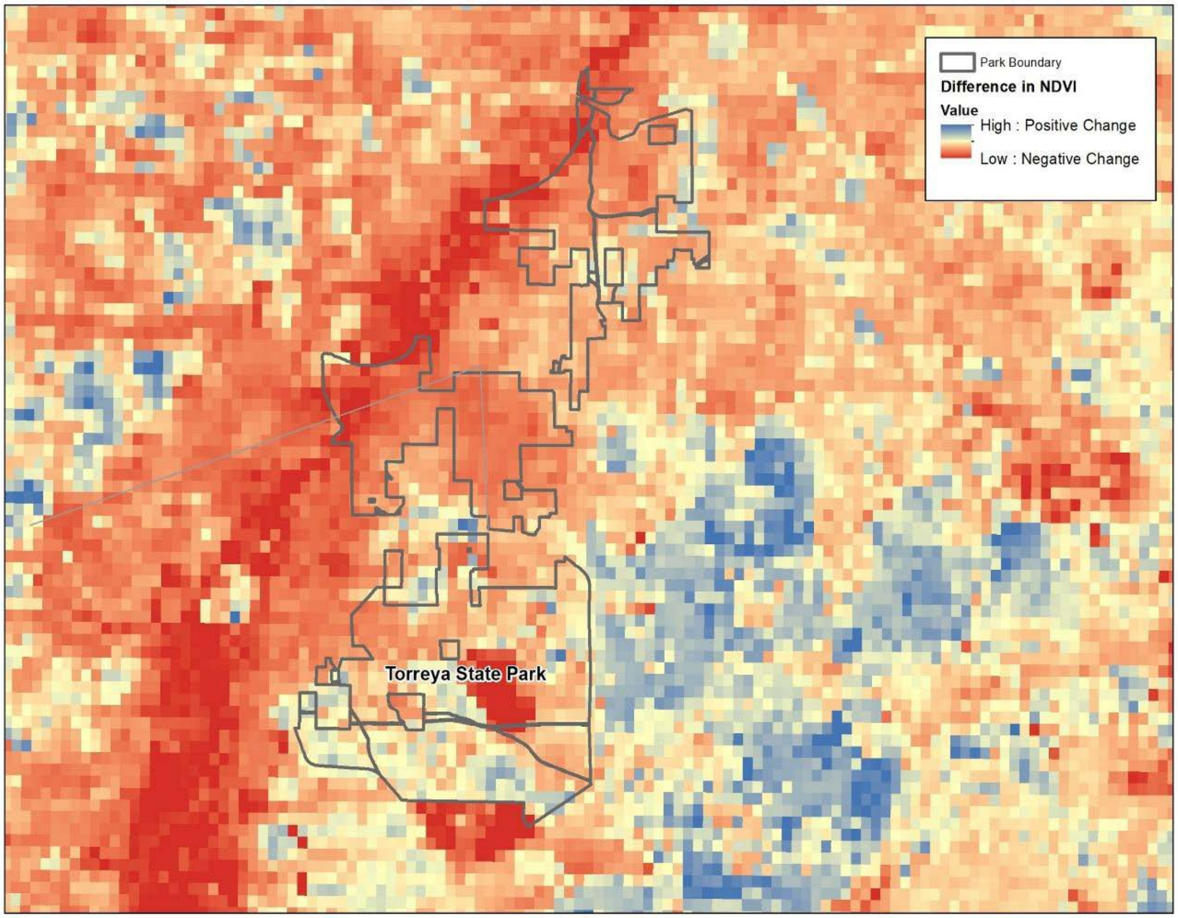

Figure 44. dNDVI estimated damage with ground/post-storm imagery

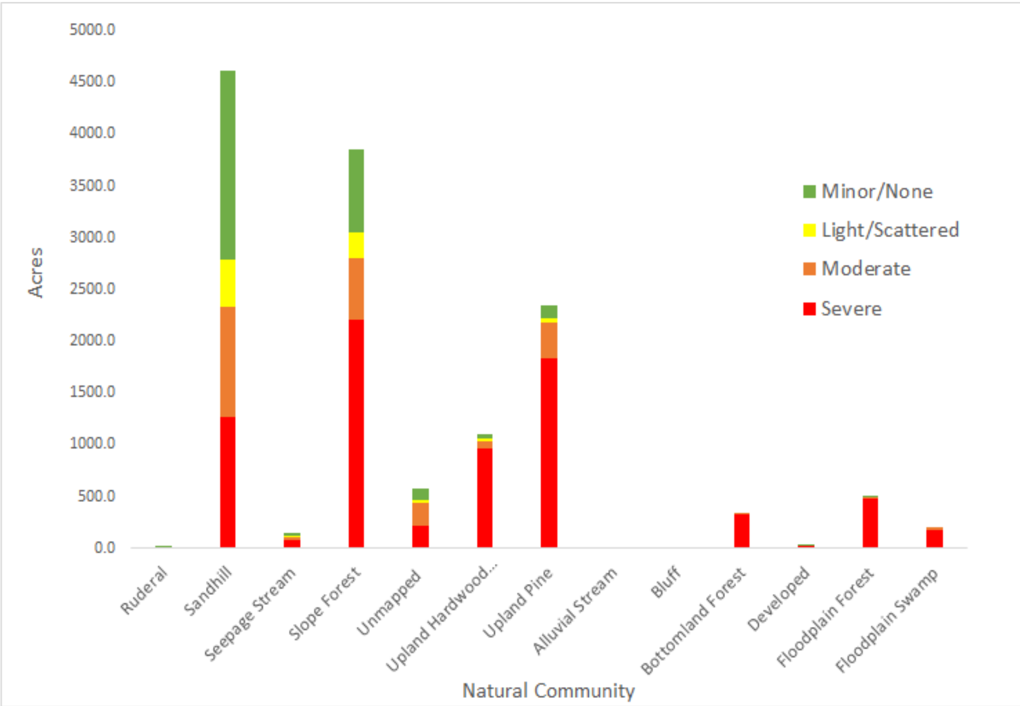

Figure 45. dNDVI Estimated Acres by Damage Class

The dNDVI indicates that the effects were generally moderate to severe for all habitat types with alluvial stream, bluff, bottomland forest and floodplain forest experiencing almost all severe impacts while sandhill and slope forest had more mixed effects (light to severe). However, these results may be influenced by the high proportion on deciduous trees in these community types. Actual mortality may be somewhat less dramatic. Sandhill had highly mixed effects, with around 50% of plots experiencing only light to minor effects.

FNAI scientists surveyed accessible areas on foot and vehicle to evaluate aspects of the habitat conditions that cannot be observed via aerial photography. We estimated fuels and other forest structure metrics (Figures 46 and 47) using standard FNAI natural community plots (see Appendix H for data form and category definitions) with photo points collected at the center of each plot (See Appendix C). Because access and time was limited, we conducted non-random assessment plots. The number of plots was determined by the range of variability found within each natural community represented. We also limited the scope of our on the ground assessments to natural communities which would have higher restoration potential (e.g. where active management is generally more appropriate). However, despite having less plots, results were similar under-sampled communities and seem representative of visual inspections on the ground.

A field assessment was completed on December 12 and January 8, 2018. FNAI scientists surveyed accessible areas on foot and vehicle to evaluate aspects of the habitat conditions that cannot be observed via aerial photography or satellite imagery. The canopies of all habitats that were observed during the short field assessment suffered variable damage, from moderate to severe, and the change this will bring to each habitat is the most significant aspect of the storm effects. The canopy damage was variable across the park, ranging from 11 to 95% removal in our plots. On average, the damage was much more moderate (~50%) (Figure 46). Upland pine and sandhill were highly variable with 13-95% of trees down in plots, allowing a fairly natural pine stand remaining in most areas due to the patchiness of damage and canopy loss (Figure 44). In some cases, especially where fire suppression or even-age regrowth occurred after logging, added homogeneity will likely benefit ground cover and longleaf seedling recruitment.

Another major change as a result of the storm was newly accumulated heavy fuel loads in the form of downed trees, limbs, and increased litter cover. Slope forest had the heaviest fuels in relation to reference conditions, followed by upland hardwood, upland pine, and sandhill. On the ground observations seemed to show overall fuel accumulations were a result of the canopy tree size and species in addition to being a function of secondary damage to midstory and understory vegetation, and not solely the number of overstory trees down. A Figure below lists a subset of other variables relevant to storm effects measured in plots (Figure 47).

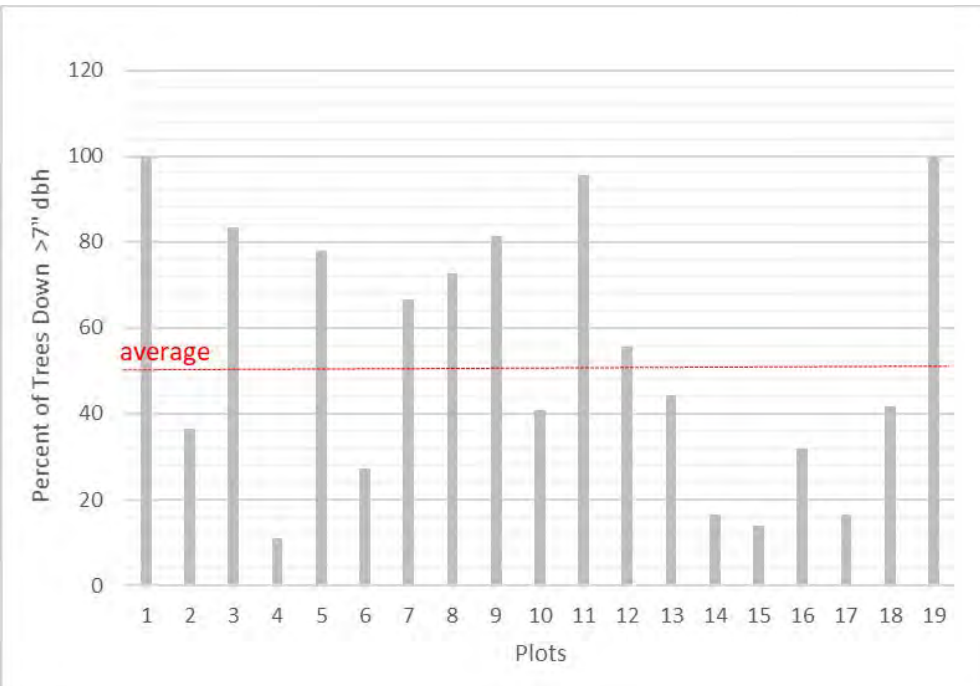

Figure 46. Percent of trees >7" dbh down in plots.

Natural Community	Canopy Height	Canopy Cover	Subcanopy Height	Subcanopy Cover	Pine Basal Area
sandhill	52.5	15.9	21.3	4.9	63.0
upland hardwood forest	45.0	40.5	30.0	20.5	0.0
upland pine	58.0	18.5	22.5	10.9	14.0
Average	**53.3**	**19.5**	**22.7**	**8.5**	**43.8**
	Fine Fuels	**Medium Fuels**	**Heavy Fuels**	**Graminoid Cover**	**Total Shrub Cover**
sandhill	3.0	3.0	3.0	40.5	2.5
upland hardwood forest	3.0	3.0	3.0	17.3	8.7
upland pine	2.6	2.8	2.8	10.7	8.1
Average	**2.7**	**2.8**	**2.8**	**14.2**	**8.0**

Figure 47. Data summary of plots. . Height measurements in feet, cover in percentages, pine basal area in ft^2/acre. For fuels low is 1, moderate, is 2, and 3 is high relative to DFCs.

At the time of the first field assessment, active tree removal was already underway at the park, focusing on the immediate needs of clearing trees on and hanging over roads, structures, and staff safety areas (picnic areas and campgrounds). The park roads and facilities were early priorities because of access to the park for visitors and structural dangers where park staff are housed and work. Most of the timber that had impacted the main road leading to the Gregory House, the campground, and the picnic area had already been removed. The Gregory House only suffered minor cosmetic damage but surrounding forests were damaged heavily (Figure 48). The campground suffered significant tree damage as did the picnic area (Figure 49). Replanting both visitor use areas may be desirable. The youth camp was not visited during the site assessment.

Figure 48. The Gregory House with canopy damage evident in adjacent slope forests.

Figure 49. The picnic area after hurricane debris was removed.

Longleaf pine habitats

Longleaf pine habitats at TSP include sandhill and upland pine. These habitats historically have an open canopy of longleaf pine (*Pinus palustris*) with a diverse herbaceous understory and occur on clayhills (upland pine) or sandy hills (sandhill). They require fire (suggested FRI 1-3 years for upland pine and sandhill and variable 2-20 years for upland mixed woodland) to maintain their open community structure with a variable herbaceous understory (FNAI 2010). Approximately half of the park was historically dominated by these pine uplands (most notably sandhill), occupying the highest elevations surrounding the ravine and riverine lowlands in the park. Much of the uplands at TSP are presently occupied by pine plantation or in the process of restoration from pine plantation, however scattered pockets of high quality habitat exist across the park including areas with intact groundcover.

Given the size of the park, inaccessibility of some areas, the rapid nature of the assessment, and many roads still being non-drivable as a result from the storm, 14 of 94 units (15%) were visited on foot with many others viewed from the roadside. Significant canopy damage was observed in most areas we visited, with varying degrees of severity. Due to their current condition based on previous land use (e.g. commercial timber and agriculture), pine uplands represent the most feasible portions of the park for pine salvage removal. Reestablishing damaged firebreaks and introducing fire as soon as possible will be important to reduce fuels and aid the recovery of the ground cover.

An area of high quality, but fragmented, sandhill is present in the Rock Creek Tract along both sides of the main entrance road in zones TY-A, TY-B, TY-C, and TY-D. A portion of this sandhill (in TY-A) was assessed during the field survey (Figure 50). An older mature canopy of longleaf is present over a high quality groundcover dominated by wiregrass, tree damage is patchy and varies between light (Figure 50) and severe (Figure 51). Only minor debris removal along hiking trails or firebreaks is recommended for such areas of where intact groundcover is present.

Figure 50. High quality sandhill in Zone TY-A with little damage to the canopy from the hurricane.

Figure 51. Severe damage to longleaf canopy in small area of Zone TY-A. These areas of severe damage were generally found along exposed ridges and hill tops.

Additional pockets of uplands (mostly sandhill with some upland pine) with intact groundcover are present throughout the Aspalaga and Rock Creek Tracts (Sweetwater Tract not assessed) and mapped based on the field surveys, aerial photography (historic and current) interpretation, and interviewing the park Biologist, Mark Ludlow. This does not represent all the intact groundcover (i.e. diverse assemblage of native groundcover including wiregrass and other graminoids and herbs) but should capture the majority of contiguous and ecologically significant patches (Figure 52).

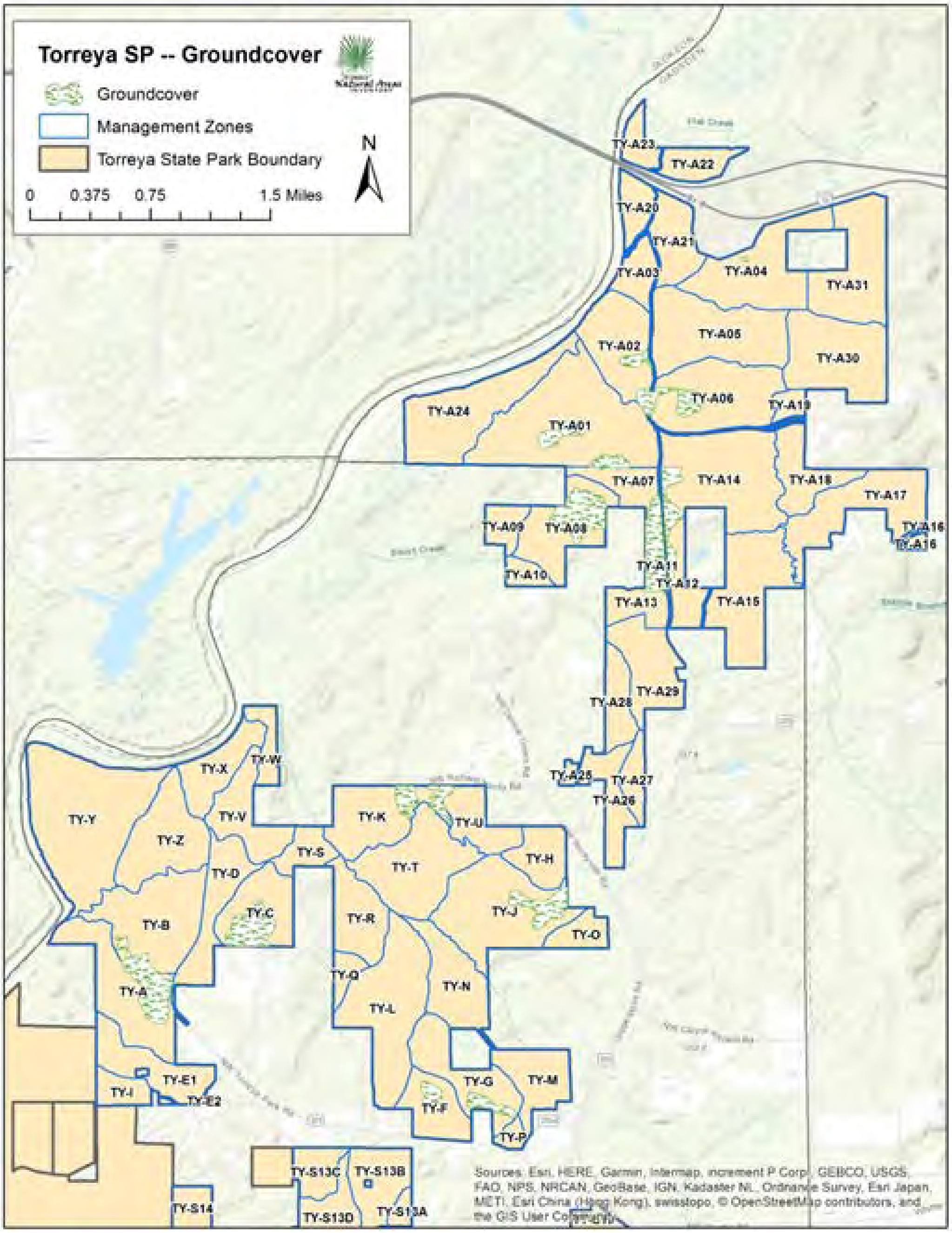

Figure 52. Areas of significant intact groundcover determined by field surveys, aerial photograph interpretation, and expert interview.

In zone TY-F, which is dominated by off-site planted slash pine, longleaf was observed along the edge of the plantation where the plantation neared the ravine edge and the habitat was fire excluded and nearing successional hardwood forest (Zone TY-F, Figures 51, 52, 55). These remnant longleaf pines represent a significant resource that, if left intact, would provide a seed source for restoration. This occurrence is likely to occur the slope forest ecotones of other plantations where it was undesirable to plant trees due to the increasing slope. This potential is also indicated by FNAI's predictive long leaf model (Figure 53).

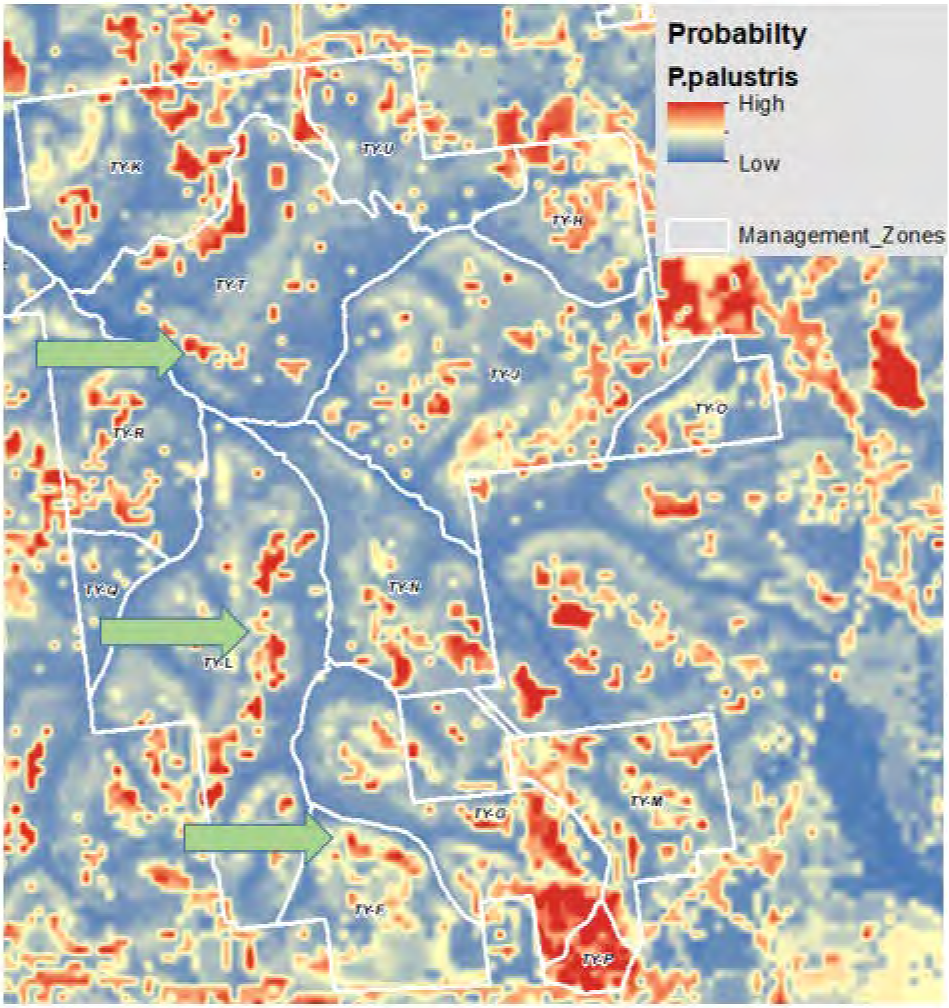

Figure 53. Indications of possible longleaf pine along upper slopes. Examples highlighted by green arrows.

Areas of the park mapped as upland hardwood forest would be good places to survey for such old remnant longleaf pines. Many hardwood forests along the uplands at the tops of the ravines likely developed through decades of fire exclusion or fire not burning all the way to the edge of the ravines. Additionally a rare plant species, Gholson's blazing star (*Liatris gholsonii*), occupies this ecotone area along the upper slopes between sandhill and the sloping hardwood dominated ravine and could potentially benefit from restoring fire to these areas. Examination of historic aerial photographs in such areas as this one (TY-F) reveals a historically open-canopied habitat rather than a closed-canopied hardwood forest. Areas such as these provide restoration opportunities to remove successional hardwoods and re-introduce fire.

The increased sunlight due to the canopy damage from the hurricane may be a long-term benefit to some of these stands in areas where fire has long been absent and the canopy was dominated by off-site pine (loblolly and slash pine) and invading hardwoods (i.e., laurel oak), currently classified as successional hardwood forest (Figure 54).

Figure 54. Successional hardwood forest between the pine plantation and ravine system in Zone TY-F with remnant longleaf pine.

Figure 55. Remnant longleaf pine between the pine plantation and ravine system in Zone TY-F.

Significant canopy damage was observed in the upland pine stands in Zones TY-A03 and TY-A21 in the northern reaches of the Aspalaga Tract. This area represented some of the heaviest damage observed in the all the parks to date as it's on a high ridge of greater than 250 feet above the Apalachicola River. As evident from the historic imagery (See Figures 60-62), heavy land clearing and soil removal occurred in this unit. As a result, this area did not have high quality groundcover before the storm and contained more exotic species than other uplands visited. Currently, the canopy is severely damaged (64-81% loss in plots) with excessive fuel loads which would inhibit successful reintroduction of fire. Many of the large hardwood trees that previously occupied the site appear to have been damaged and the remaining standing trees are pines (mostly older loblolly pine). This may be a suitable Zone for salvage given the heavy amount of downed trees and the accessibility via Aspalaga Road.

Several pine plantations were observed during the survey with extremely variable damage from light damage in the sand pine plantations along NW Torreya Park Road in the Sweetwater Tract, light to moderate damage in the plantations along Aspalaga Road in Zones TY-A6 and TY-A14 (some of which were already marked for thinning; Figure 56), to heavy damage along NW Torreya Park Road in the Rock Creek Tract (Zone TY-F). Post-storm aerial photo/satellite interpretation of plantations in the Sweetwater Tract with post-storm photos indicate that damage to those plantations is not as severe as other areas of the park further north. The pine plantation in Zone TY-F was heavily damaged. However, units such as TY-F plantation may have benefited from hurricane thinning as they now are closer to the desired stand density, basal area, and canopy cover (Figure 57). Given its high profile location on the road directly into the park, TY-F is a potential area for restoration and educational interpretation.

Figure 56. Pine plantation along Aspalaga Road in TY-A14.

Figure 57. Older portion of the slash pine plantation with heavy damage in Zone TY-F.

Hardwood Forest

There were a number of areas of the park that were not field assessed due to water/time constraints or because of priorities for timber assessment. This does not indicate that the resources are not valuable, just that timber removal is not necessary and/or time sensitive for salvage. These resources will be addressed in the restoration plan.

In the closed canopied habitats such as floodplain swamp, alluvial forest, bottomland forest, upland hardwood forest, and slope forest (see FNAI 2010), the increased sunlight will drastically change the microclimate of these formerly closed-canopy forests. The successional changes that will occur over the next 20-50 years in each of these habitats is unknown at this point. Early successional species, such as laurel cherry (*Prunus caroliniana*), and invasive species, such as Japanese climbing fern (*Lygodium japonicum*), heavenly bamboo (*Nandina domestica*), Japanese honeysuckle (*Lonicera japonica*), or Chinese privet (*Ligustrum sinense*), may show dramatic increases in the immediate future. Community structure and composition monitoring would allow us to document and better understand these successional transitions.

During the field assessment the forested wetland habitats (bottomland forest, alluvial forest) were not assessed but canopy damage in the Apalachicola River floodplain is significant and very evident on recent aerial photography. Canopy damage may now appear worse than it actually is due to the fact that the deciduous species are mostly leafless now. After leaf out in the spring the full extent of canopy damage can be truly assessed and the canopy may appear healthier than it currently does. Aside from areas of public access, these forests will likely just need to recover on their own.

As with the forested wetlands significant canopy damage occurred in the slope forests (Figures 58 and 59). These are limited rich hardwood communities with mixed canopies on ravine slopes dominated by a diverse suite of species including deciduous trees such as white oak (*Quercus alba*), Florida maple (*Acer saccharum* ssp. *floridanum*), and American beech (*Fagus grandifolia*), and evergreen species such as southern magnolia (*Magnolia grandiflora*), live oak (*Quercus virginiana*) and spruce pine (*Pinus glabra*) among others. Several rare tree species occupy this globally significant habitat including American bladdernut (*Staphylea trifolia*), Florida yew (*Taxus floridana*), Florida torreya (*Torreya taxifolia*), The dense canopy and multiple layers of midstory vegetation restrict air movement and light penetration, which maintains high relative humidity within this community. The groundcover is made up of shade-tolerant herbs, graminoids, shrubs, and vines, several of which are rare in Florida and/or more common further north (i.e., narrow-leaved trillium (*Trillium lancifolium*), croomia (*Croomia pauciflora*), Carolina lily (*Lilium michauxii*) and eastern leatherwood (*Dirca palustris*) among many others). Given the significant canopy loss due to Hurricane Michael, the delicate microclimate of these areas will undoubtedly be changed causing unknown effects to the community structure and composition that will need to be evaluated through monitoring of vegetation changes. A concern of note is how the fragile spring ephemerals in the ground layer of this habitat at TSP will respond to the change in light availability. Invasive species are another particular concern, especially in the areas where limestone outcrops are present. These forests are not areas where salvage logging is appropriate because of their rare resources and fragile microclimate and will likely need to recover on their own aside from areas where downed trees need to be removed because of public safety concerns. All rare plant populations should be revisited to evaluate post-hurricane health when phenologically appropriate.

Figure 58. Rich slope forest with heavy canopy damage in Zone TY-X near the Gregory House.

Figure 59. Needle palm in slope forest with heavy canopy damage in Zone TY-Z.

Task 3: Restoration Evaluation

For those areas of the park not being considered for timber salvage, options to consider include: prescribed burning, native planting, native seeding, mechanical removal of vegetation, and chemical control of exotic species (could be conducted in all areas with hazard tree removal). The purpose here is to outline what actions can be taken in the near term. Many actions, such as groundcover restoration and pine planting, would likely occur outside of the near term actions. Near term actions will mainly consist of preparing a site for restoration (e.g. timber or brush removal), except in portions of that have already been cleared. The Park could consider outplanting longleaf pines immediately in TY-H. In addition, the park could consider thinning and removing downed trees from plantations and other units identified as high priority under the current timber contract. In addition, we recommend that DEP continue to work with experts of reintroduction and recovery of *Conradina glabra* and *Torreya taxifolia*.

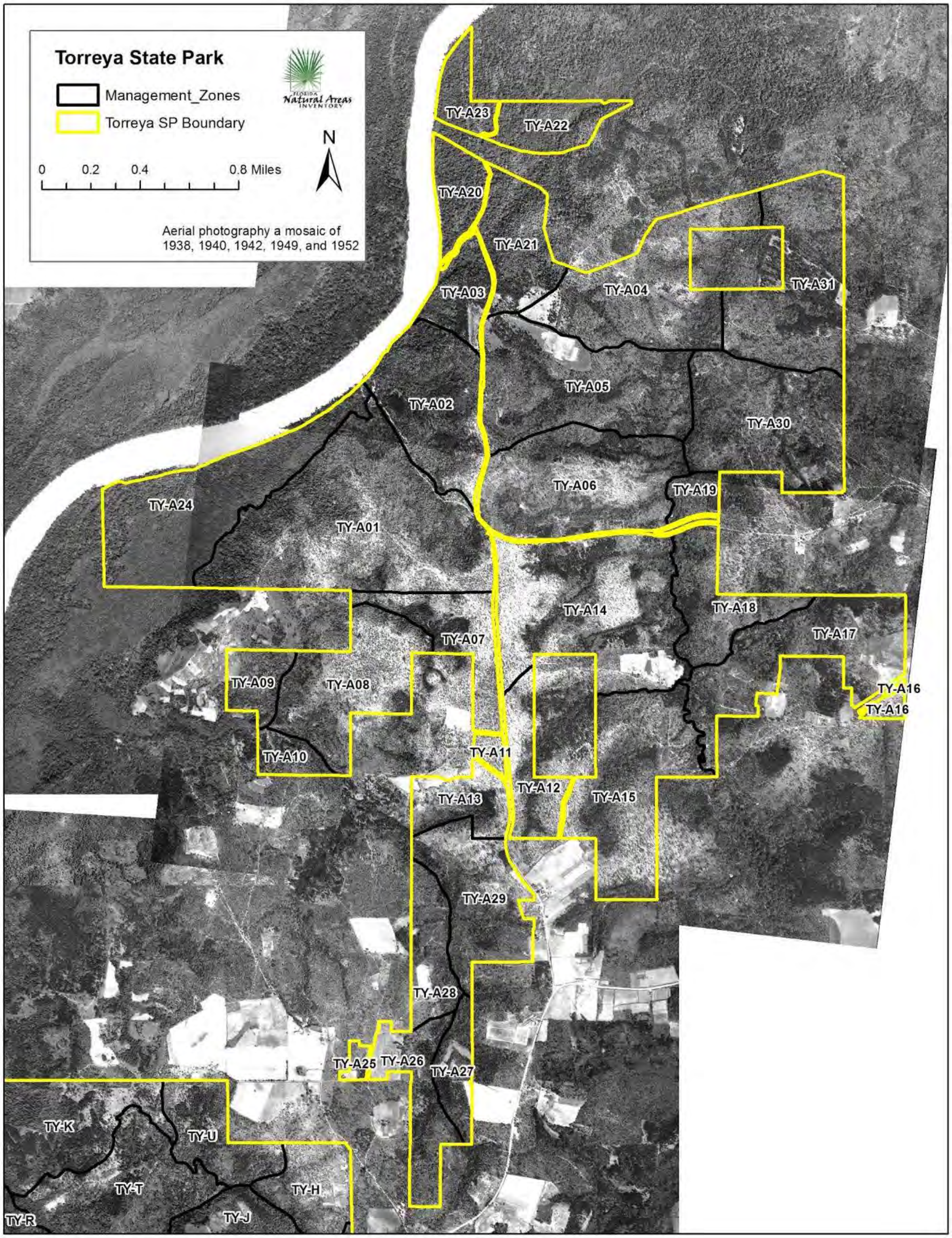

Figure 60. Torreya State Park, Aspalaga Tract Management Units with aerial photography in a mosaic from 1938, 1940, 1942, 1949, and 1952.

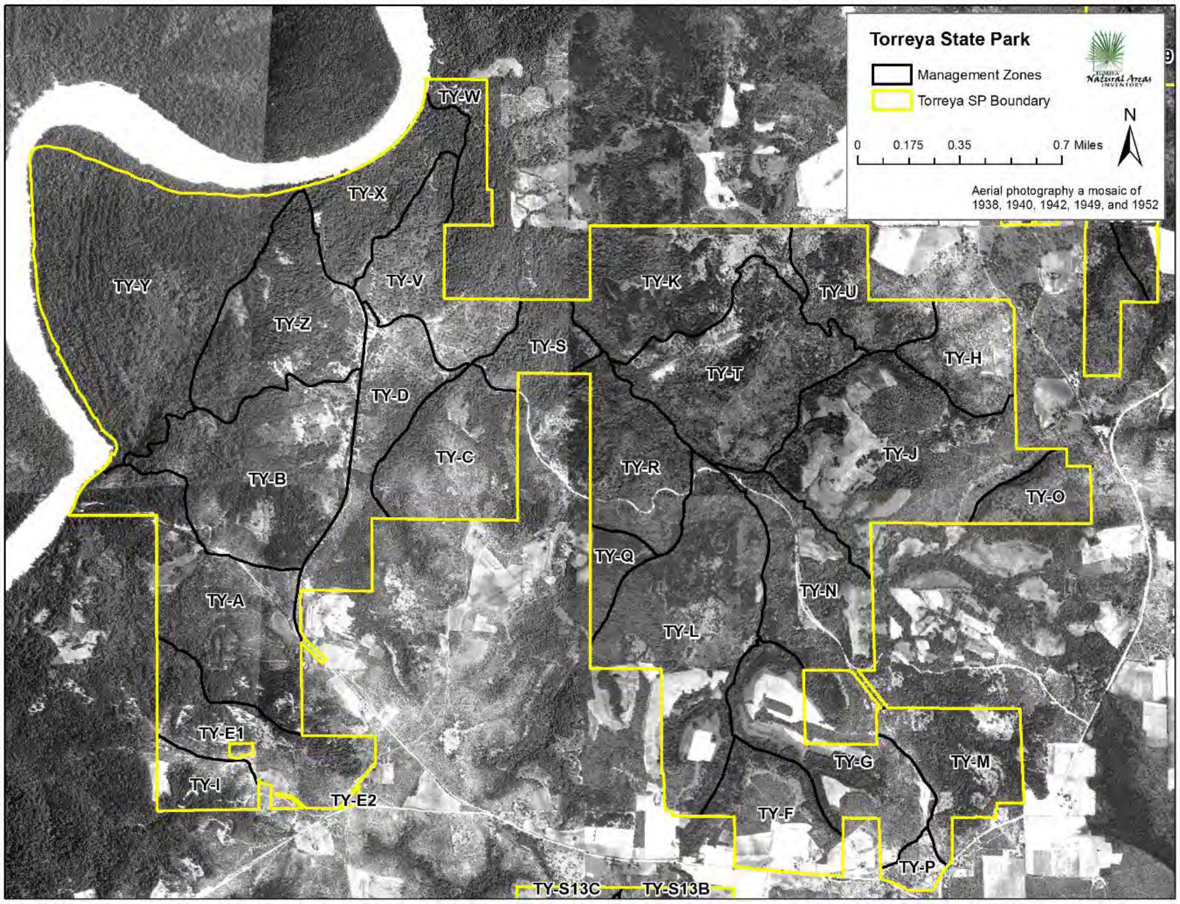

Figure 61. Torreya State Park, Rock Creek Tract Management Units with aerial photography in a mosaic from 1938, 1940, 1942, 1949, and 1952.

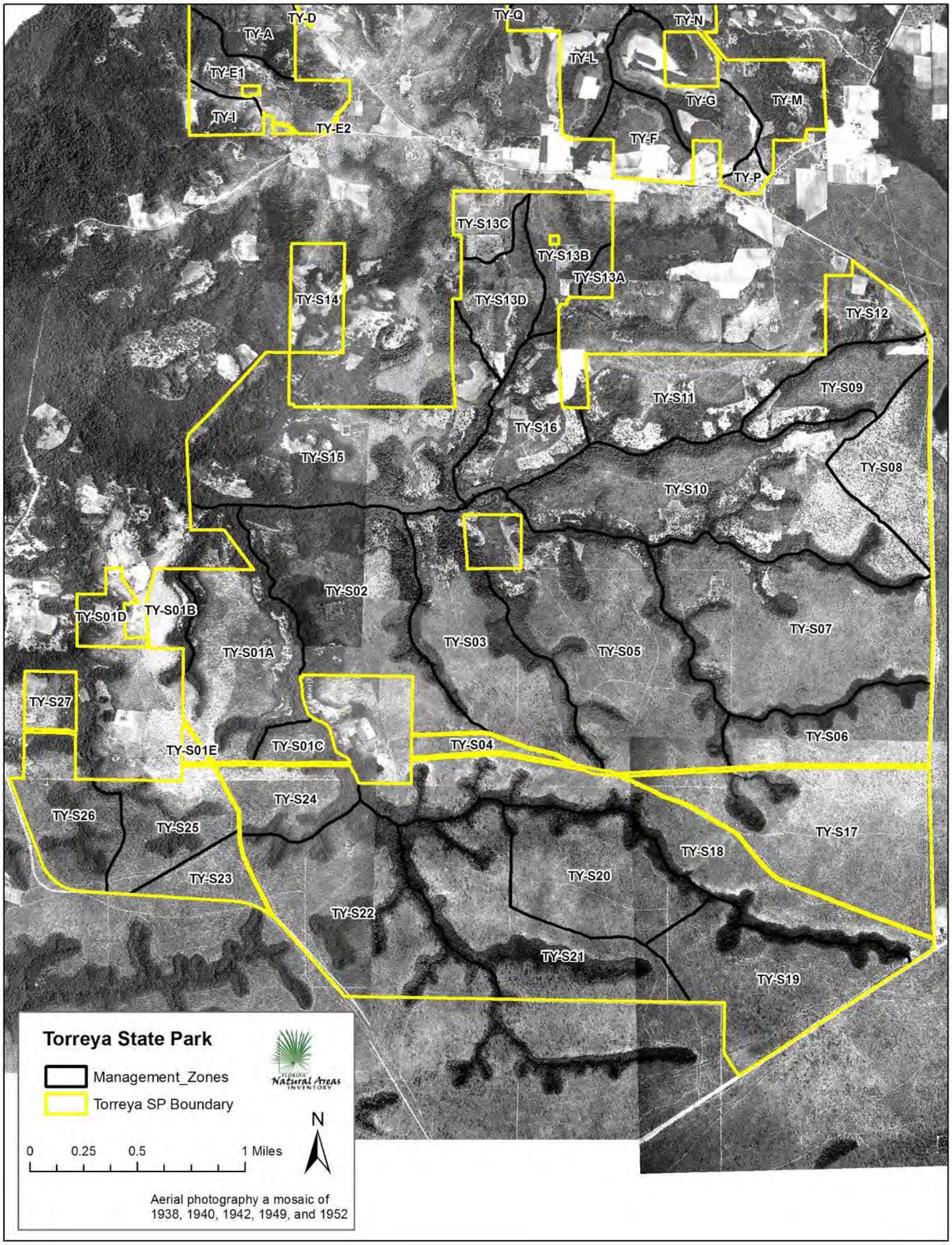

Figure 62. Torreya State Park, Sweetwater Tract Management Units with aerial photography in a mosaic from 1938, 1940, 1942, 1949, and 1952.

Falling Waters State Park

Management Context Related to Restoration Activities

The purpose of Falling Waters State Park is to protect a series of sinkholes, particularly the chimney sinkhole that Florida's highest waterfall cascades into before disappearing into the park's network of terrestrial caves. The park also highlights the historical legacy of the region due to its ideal location and resources while providing resource-based outdoor recreation and preserving the unique natural features. In the management of a state recreation area, major emphasis is placed on maximizing the recreational potential of the unit. However, preservation of the park's natural and cultural resources remains important. Depletion of a resource by any recreational activity is not permitted. In the 2017 management plan, it was determined that timber management could be accommodated in a manner that would be compatible and not interfere with the primary purpose of resource-based outdoor recreation and conservation. This compatible secondary management purpose is addressed in the Resource Management Component of the plan.

Park Management Goals

The following park goals express DRP's long-term intent in managing the state park:

1. Provide administrative support for all park functions.
2. Protect water quality and quantity in the park, restore hydrology to the extent feasible and maintain the restored condition.
3. Restore and maintain the natural communities/habitats of the park.
4. Maintain, improve or restore imperiled species populations and habitats in the park.
5. Remove exotic and invasive plants and animals from the park and conduct needed maintenance-control.
6. Protect, preserve and maintain the cultural resources of the park.
7. Provide public access and recreational opportunities in the park.
8. Develop and maintain the capital facilities and infrastructure necessary to meet the goals and objectives of this management plan.

Task 1: Rapid Assessment of Timber Salvage Options

Because the damage was relatively minor, there is no need to assess timber options. Park managers have already removed timber from campground and other park infrastructure. Scattered trees may be present in the interior of management units, but the manager has instructed employees to limb trees and leave the tree bole in place.

Task 2: Rapid Damage Assessment

Rapid damage assessment was conducted at two scales: using remote sensing and on the ground with plots and visual observations. First, damage was assessed through remote sensing using normalized difference vegetation index (NDVI). NDVI is a simple graphical indicator that assesses whether the target being observed contains live green vegetation; this has been used effectively to assess storm damage

(Wang et al. 2010). Because of the small size of Falling Waters, FNAI used the difference in Sentinel satellite processed U.S. Forest Service (ForWarn II) derived NDVI ("dNDVI"; Figure 63). Sentinel satellite provides NDVI values at a 10x10 meter scale, but has less comparable "pre" images than MODIS which can introduce addition error. Some factors which need to be considered when interpreting NDVI readings are: 1) areas dominated by grass, standing water, or impervious surface may alter results; 2) other landuse changes within the last year (e.g. fire, logging, etc.); 3) actual damage to deciduous trees could be overestimated and 4) trees, especially pines, may not have fully browned. As with the other sites, MODIS dNDVI values were assigned to damage class bins which were created using post storm imagery and U.S. Forest Service hurricane fuels assessment categories (Figure 64).

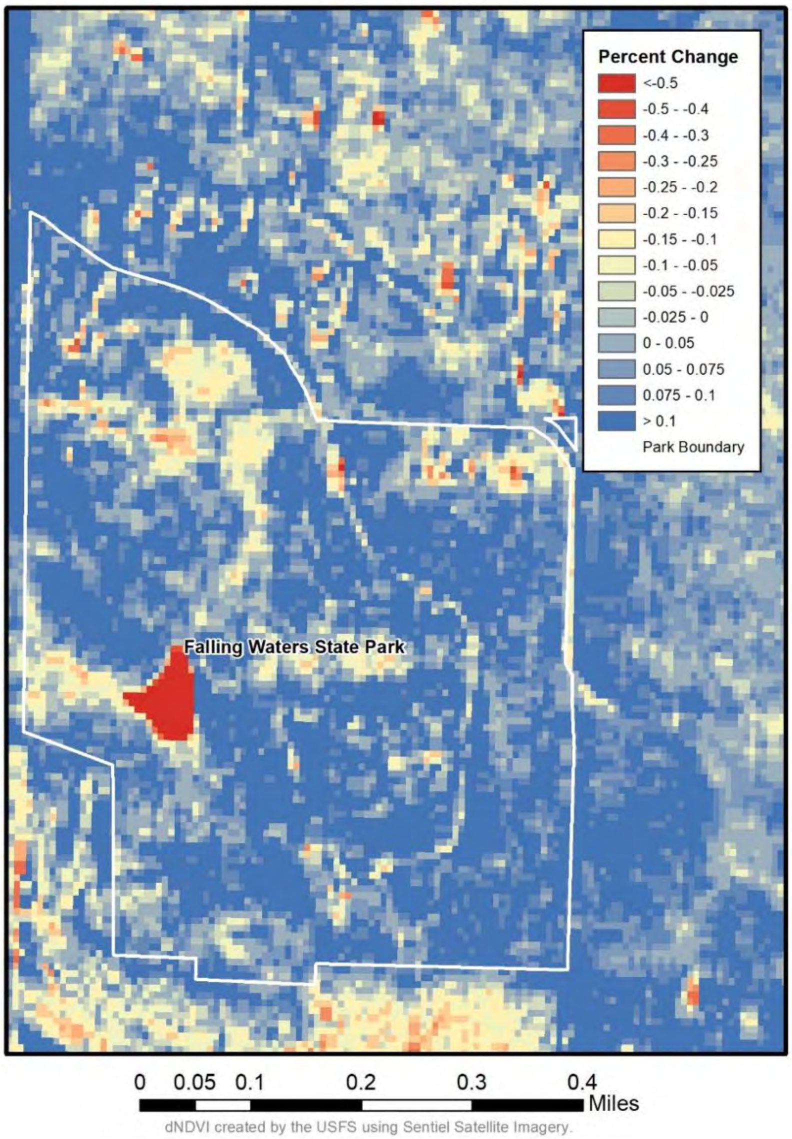

Figure 63. The dNDVI shows relatively low change values indicating light to moderate damage which is consistent with on the ground inspections.

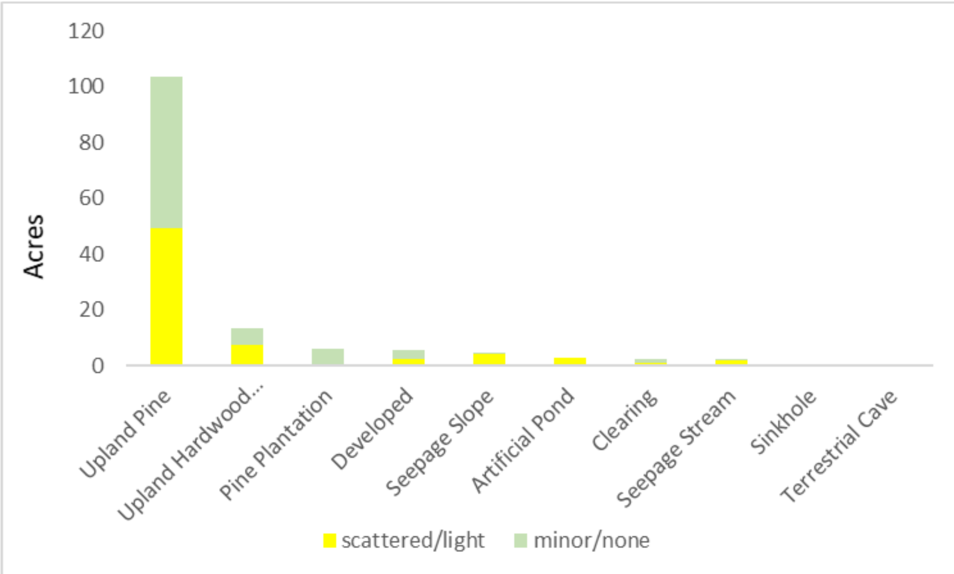

Figure 64. dNDVI Estimated Acres by Damage Class

FNAI scientists surveyed accessible areas on foot and vehicle to evaluate aspects of the habitat conditions that cannot be observed via aerial photography. We estimated fuels and other forest structure metrics (Figures 65 and 66) using standard FNAI natural community plots (see Appendix H for data form and category definitions) with photo points collected at the center of each plot (See Appendix D). Because access and time was limited, we conducted non-random assessment plots. The number of plots was determined by the range of variability found within each natural community represented. We also limited the scope of our on the ground assessments to natural communities which would have higher restoration potential (e.g. where active management is generally more appropriate). However, despite having less plots, results were similar in under-sampled communities and seem representative of visual inspections on the ground.

A field assessment was completed on January 15, 2018. The canopy damage varied across the park, ranging from 0 to 47% of trees >7" dbh downed in our plots. On average, the damage was light (20%) (Figure 64). The majority of plots were in upland pine/sandhill; the highest proportion of downed trees per plot observed was 47% and the lowest was 0% with an average of 20%. The plot in upland hardwood had 20% of trees down.

Another change is the heavy fuel load from downed trees, limbs, and increased litter cover. All plots detected light to moderate fuel loads in all three fuels classes (Figure 65). On the ground observations were that overall fuel accumulations were minimal as a result of the storm. Managers have already remediated the largest concentration of fuels in small areas where heavy damage existed. Figure 66 below lists other variables measured in the plots.

Figure 65. Percent of trees down in all plots at Falling Water State Park.

Natural Community	Canopy Height	Canopy Cover	Subcanopy Height	Subcanopy Cover	Pine Basal Area
sandhill	52.5	20.5	22.5	0.5	70.0
upland hardwood forest	37.5	50.5	10.5	20.5	0.0
upland pine	57.5	16.1	16.5	0.3	55.5
Average	**55.6**	**19.1**	**16.5**	**1.8**	**52.3**
	Fine Fuels	**Medium Fuels**	**Heavy Fuels**	**Graminoid Cover**	**Total Shrub Cover**
sandhill	3.0	1.0	0.0	60.5	20.5
upland hardwood forest	2.0	2.0	2.0	0.5	20.5
upland pine	2.9	2.2	2.1	48.9	14.3
Average	**2.8**	**2.1**	**1.9**	**46.0**	**15.3**

Figure 66. Data summary of plots. . Height measurements in feet, cover in percentages, pine basal area in ft^2/acre. Ranked fuels low is 1, medium is 2, and 3 is high.

At the time of the field assessment, tree removal was already underway and mostly complete at the park, focusing on the immediate needs of clearing trees on and hanging over roads, structures, and staff safety areas (picnic areas and campground). The park was the in progress of delimbing downed trees and planned to leave the boles within the interior of units. The areas within and near the campground was mostly cleared of large trees during the work that has already been completed. The campground has been planted with annual ryegrass to stabilize exposed soil caused during the tree and debris removal. Given its visibility to the public, the campground may be a restoration priority for replanting with native species.

Longleaf pine habitats

Longleaf pine habitats at FWSP are dominated by upland pine on clay hills. Smaller areas of sandhill habitat are present in isolated patches of sandy soils. Both of these natural communities are historically characterized by an open-stature canopy of longleaf pine (*Pinus palustris*) and a primarily herbaceous understory dominated by wiregrass (*Aristida stricta*). These characteristics are still evident today as a result of frequent prescribed burning as both habitats require fire (suggested FRI 1-3 years) (FNAI 2010). The upland pine/sandhill habitats at FWSP are, for the most part, in excellent (reference quality) condition with an older mature canopy of longleaf pine, low shrub cover, and an herbaceous groundcover dominated by a dense stands of wiregrass.

At the time of the field survey, the wiregrass in Zone FW-B had evidence of a healthy flowering (Figure 66), the result of a growing season burn in 2018. Minor canopy damage was observed in most areas we visited (Figures 67 and 68). Several small areas where moderate damage (Figure 69), and a few small sites of heavy damage (Figure 70) were also recorded. At the time of the field survey most of the damaged trees had been cut and left on the forest floor. The manager stated that crews also cut up the canopies of the downed trees to blend in more with the landscape aesthetically. Continuing to introduce fire regularly under diverse conditions with an emphasis on growing season burns when possible is the only management action needed to maintain desired conditions to restore storm damaged areas.

Figure 67. Minor canopy damage in high quality upland pine in Zone FW-B with evidence of significant wiregrass bloom. Damaged trees have been dropped and canopies trimmed to blend in more with the landscape aesthetically.

Figure 68. Upland pine with light damage in Zone FW-B.

Figure 69. Upland pine with moderate damage.

Figure 70. Heavy damage in upland pine in Zone FW-B.

A few small areas were observed where heavier tree clearing had occurred and created some ground disturbance. Fire should help these areas rehabilitate and monitoring of these areas for invasive plant species recruitment is recommended. One such area is along the paved road in Zone FW-A (Figure 71). Wiregrass was dense here prior to the equipment impacts and is currently damaged but may recover as it was still green at the time of the survey. This is a very small portion of the overall excellent quality habitat.

Figure 71. Small section of Zone FW-A along the paved road where tree damage was heaviest and small scale soil disturbance to the groundcover was observed due to tree removal.

Upland Hardwood Forest

Upland hardwood forests are mixed canopy forests dominated by a diverse suite of species including American beech (*Fagus grandifolia*) and pignut hickory (*Carya glabra*), and evergreen species such as southern magnolia (*Magnolia grandiflora*), and laurel oak (*Quercus hemisphaerica*) among others. The dense canopy of upland hardwood forests and multiple layers of midstory vegetation restrict air movement and light penetration, which maintains high relative humidity within this community. The groundcover is made up of shade-tolerant herbs, graminoids, and vines such as sarsaparilla vine *(Smilax pumila*) and partridgeberry (*Mitchella repens*). In closed canopied habitats such as upland hardwood forest (see FNAI 2010), increased sunlight caused by tree damage from the hurricane can drastically change the microclimate of these formerly closed canopied forests. The successional changes that will occur over the next 20-50 years in such habitats are unknown at this point. However, damage is fairly minimal at this site (Figure 72). Minor canopy damage occurred in the upland hardwood forest at FWSP (Figure 72) with about 20% of trees knocked down. Canopy cover is still fairly high, with about 50% canopy cover and 20% subcanopy cover. Early successional species, such as laurel cherry (*Prunus caroliniana*), and invasive species, such as Japanese climbing fern (*Lygodium japonicum*) or Chinese privet (*Ligustrum sinense*), may show increases within newly formed canopy gaps. Community structure and composition monitoring post storm is recommended to document and better understand these successional transitions. Aside from areas of public access where safety concerns need to be addressed, we recommend exotic plant treatment and passive restoration (i.e. natural succession).

Figure 72. Upland hardwood forest near the falls in the south portion of Zone FW-B.

Task 3: Restoration Evaluation

For those areas of the park not being considered for hurricane restoration by timber removal, options to consider include: prescribed burning, native planting, native seeding, mechanical removal of vegetation, and chemical control of exotic species (could be conducted in all areas with hazard tree removal). In this document we outlined actions that can be taken in the near term (within 90 days). Many actions, such as groundcover restoration and pine planting, would likely occur outside of the near term actions. Near term actions will mainly consist of preparing a site for restoration (e.g. timber or brush removal), except in portions of that have already been cleared. The Park could consider outplanting longleaf pines immediately. However, this document will outline the types of restorations that need to be considered in order to facilitate the early planning phase of the restoration (post 90 days).

Recommendations Based on Historic and Current Conditions

Aerial photography from 1949 indicates that most of the park was historically dominated by upland pine with sandhill occupying smaller, sandier soil areas (Figure 73). The northwestern and southwestern corners (portions of Zones FW-E, FW-D, and FW-C) were cleared for agriculture as early as 1949.

The northwest corner of the park was cleared historically (as evidenced in the 1949 photography, See Task 3, Figure 73) and therefore is significantly different from the excellent quality habitat nearby in the forest. The area south of the campground in Zone FW-C has a canopy of slash and loblolly pine (*Pinus elliottii* and *Pinus taeda*), lacks wiregrass, and has a higher shrub cover than the rest of the park (36-45% cover compared with variable including <1% to 16-25% cover in the remaining areas of the park). Canopy damage in this portion is heavy (Figure 74) and this could be an area where small-scale timber removal followed by replanting with longleaf pine and wiregrass could benefit this small portion of Zone FW-C.

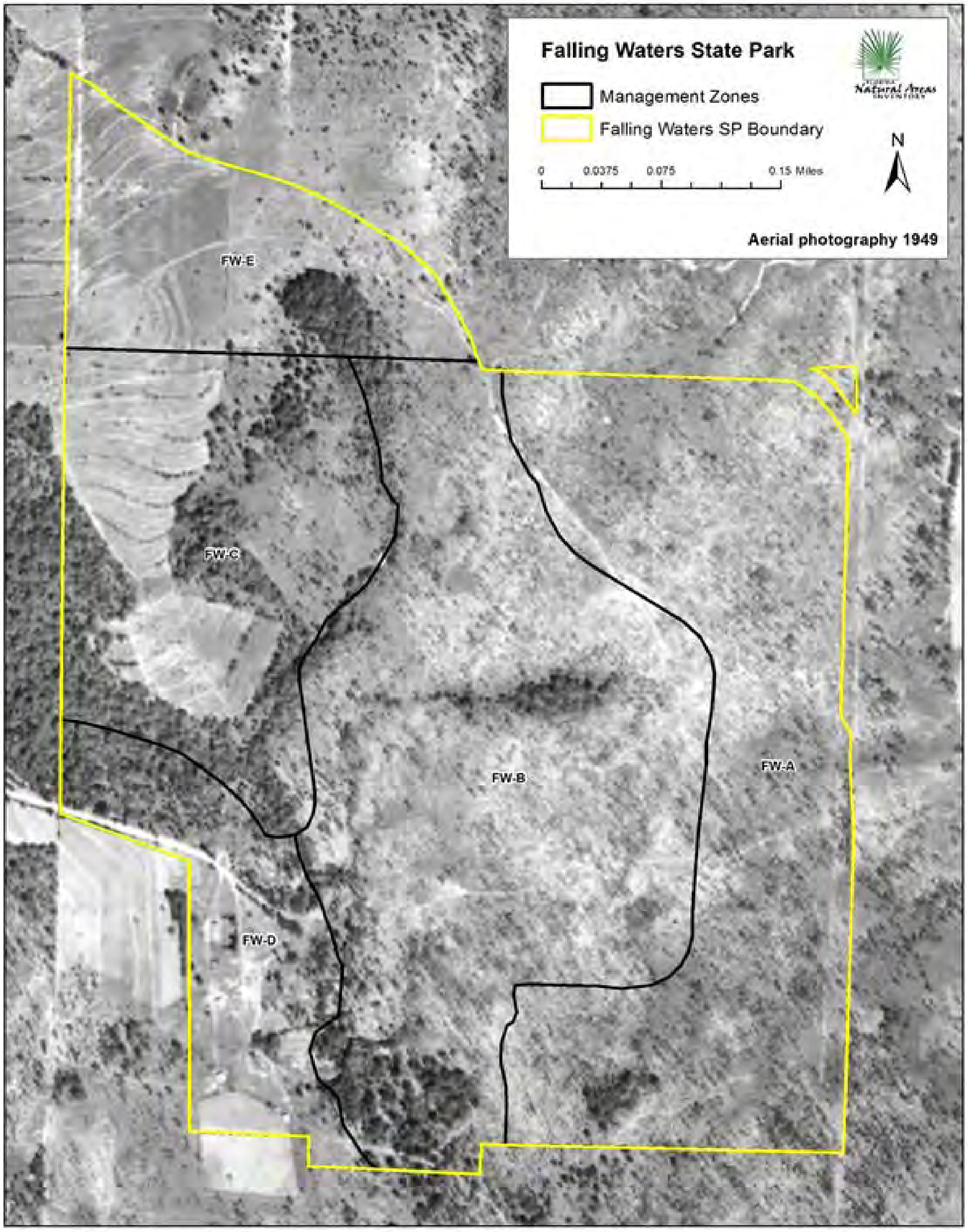

Figure 73. Falling Waters State Park management units with 1949 aerial photography.

Figure 74. Heavy damage in upland pine just south of the campground in Zone FW-C.

Dr. Julian G. Bruce St. George Island State Park

The purpose of St. George Island State Park (SGISP) is to provide for resource-based public outdoor recreational activities, especially saltwater beach activities, camping and hiking (DEP 2016a). The park has a mosaic of dune and swales with ridges of upland pines. SGISP is well known for its exemplary beach dune and coastal grasslands in addition to the numerous shorebird species which inhabit the park.

Management Context Related to Restoration Activities

DRP's philosophy of resource management places primary emphasis on restoring and maintaining, to the degree possible, the natural processes that shaped the structure, function and species composition of Florida's diverse natural communities as they occurred in the original domain. In the 2016 management plan, it was determined that the primary management objectives of the unit could be met without conducting timber management activities for this management plan cycle.

Park Management Goals

The following park goals express DRP's long-term intent in managing the state park.

1. Provide administrative support for all park functions.
2. Protect water quality and quantity in the park, restore hydrology to the extent feasible and maintain the restored condition.
3. Restore and maintain the natural communities/habitats of the park.
4. Maintain, improve or restore imperiled species populations and habitats in the park.
5. Remove exotic and invasive plants and animals from the park and conduct needed maintenance-control.
6. Protect, preserve and maintain the cultural resources of the park.
7. Provide public access and recreational opportunities in the park.
8. Develop and maintain the capital facilities and infrastructure necessary to meet the goals and objectives of this management plan.

Task 1: Rapid Assessment of Timber Salvage Options

Because the damage was relatively minor, there is no need to assess timber salvage options. Park managers have already removed timber from campground and other park infrastructure. All units were assessed using the RRAM tool (Figure 1) however, none were identified to be evaluated for potential timber operations

Task 2: Rapid Damage Assessment

Rapid damage assessment was conducted at two scales: using remote sensing and on the ground with plots and visual observations. First, damage was assessed through remote sensing using normalized difference vegetation index (NDVI). NDVI is a simple graphical indicator that assesses whether the target being observed contains live green vegetation; this has been used effectively to assess storm damage (Wang et al. 2010). Using MODIS satellite imagery, FNAI determined the difference in NDVI (dNDVI) from October 2017 to October 2018 (Figure 75) and then applied the values to natural communities and park boundaries MODIS satellite imagery provides NDVI values at a 250x250 meter scale. Even though St. George Island is relatively small, we used MODIS as coverage was not available from Sentinel data as it was for Falling Waters. Some factors which need to be considered when interpreting NDVI readings are: 1. areas dominated by grass, standing water, or impervious surface may alter results; 2) other landuse changes within the last year (e.g. fire, logging, etc.); 3) actual damage to deciduous trees could be overestimated and 4) trees, especially pines, may not have fully browned. Next, dNDVI values were assigned to damage class bins which were created using post storm imagery and U.S. Forest Service hurricane fuels assessment categories (Figure 76).

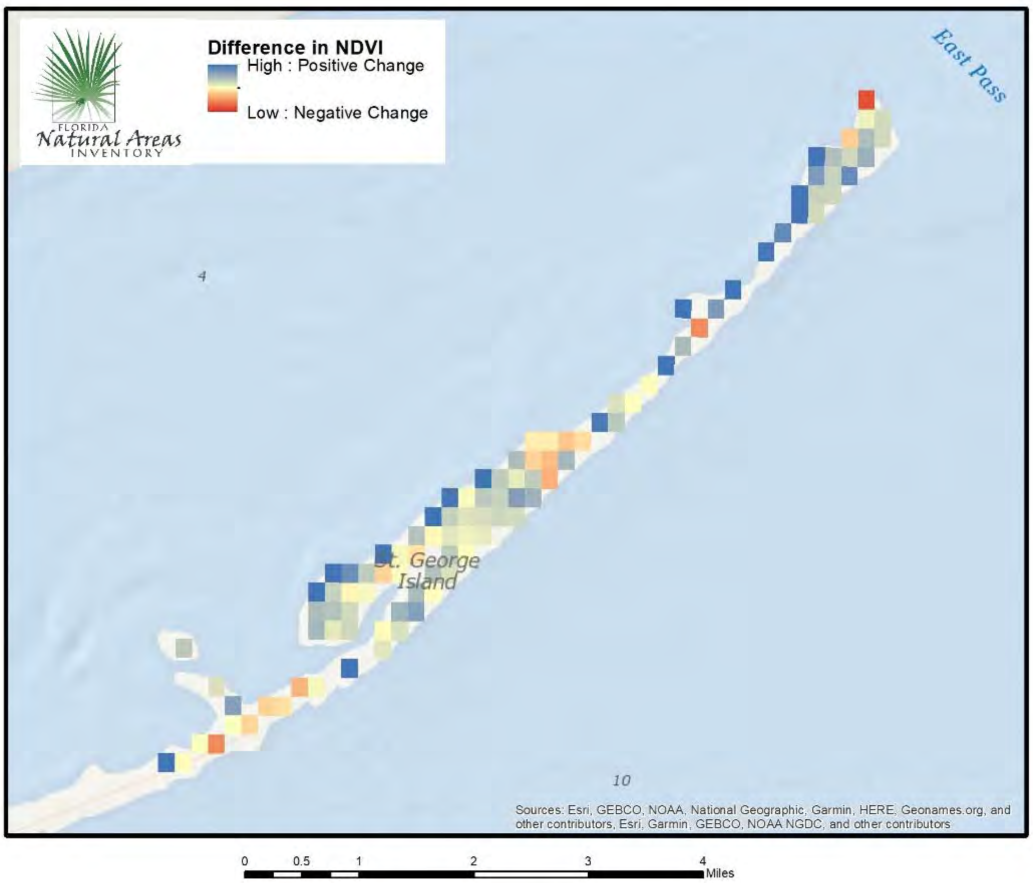

Figure 75. The dNDVI shows relatively low change values indicating light to moderate damage which is consistent with on the ground inspections.

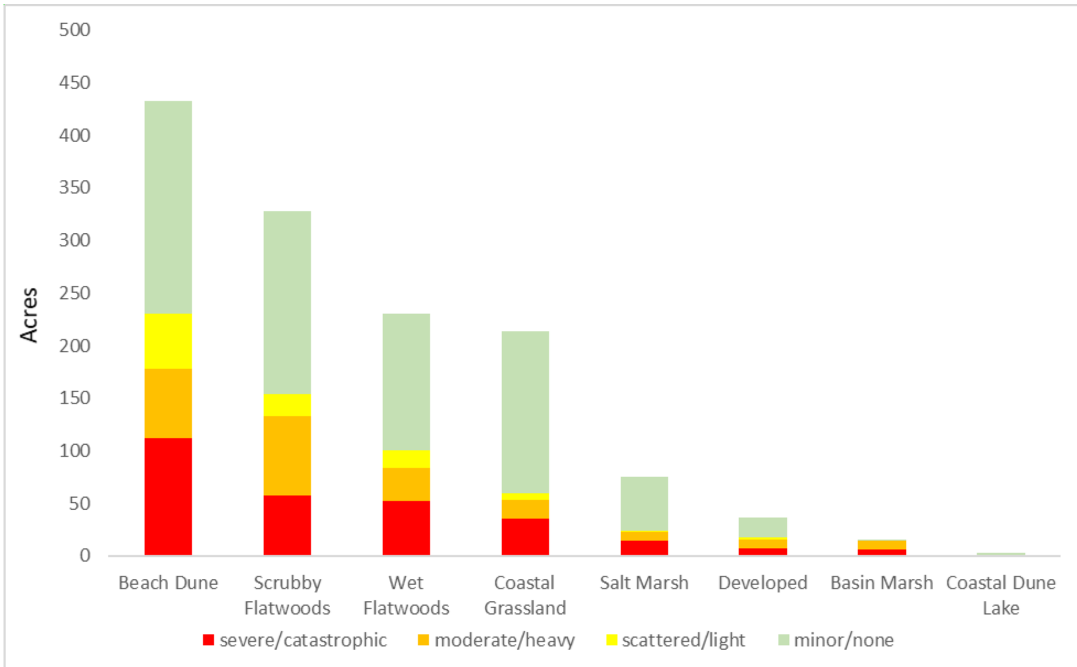

Figure 76. dNDVI Estimated Acres by Damage Class.

FNAI scientists surveyed accessible areas on foot and vehicle to evaluate aspects of the habitat conditions that cannot be observed via aerial photography. We estimated fuels and other forest structure metrics (Figures 77 and 78) using standard FNAI natural community plots (see Appendix H data form and category definitions) with photo points collected at the center of each plot (See Appendix E). Because access and time was limited, we conducted non-random assessment plots. The number of reference plots was determined by the range of variability found within each natural community represented. We also limited the scope of our on the ground assessments to natural communities which would have higher restoration potential (e.g. where active management is generally more appropriate). However, despite having fewer plots, results were similar in under-sampled communities and were representative of visual inspections on the ground.

A field assessment was completed on January 30, 2019. Much of the park was overwashed with a significant storm surge which heavily eroded dunes (especially primary dunes), damaged structures, deposited heavy layers of storm debris (plant material and trash), and caused some minor tree death (young slash pines (*Pinus elliottii*) in the coastal grasslands) because of salt water damage.

The most significant change to pine dominated natural communities as a result of the storm was tree damage. Generally, the canopies of all habitats that were observed during the field assessment had experienced some damage. The damaged trees are both blown down from the roots, the stem broken forming “A frames”, or the trees are standing dead from salt water influence. Damage was generally light in most places with downed trees observed ranging from 0 to 46% in our plots (Figure 77). On average, damage was light (9%) (Figure 77). Downed and dead trees result in increased fuel loads and increased sunlight availability to the ground layer. Increased sunlight to the forest floor may increase herbaceous plant diversity and abundance but this may be mitigated by the increased fine fuels present post storm. Increased fine fuels from storm damage may increase the risk of wildfire under dry conditions but also allow for better fuel continuity for prescribed burns done under more favorable conditions. A table below lists other variables measured in the plots (Figure 78).

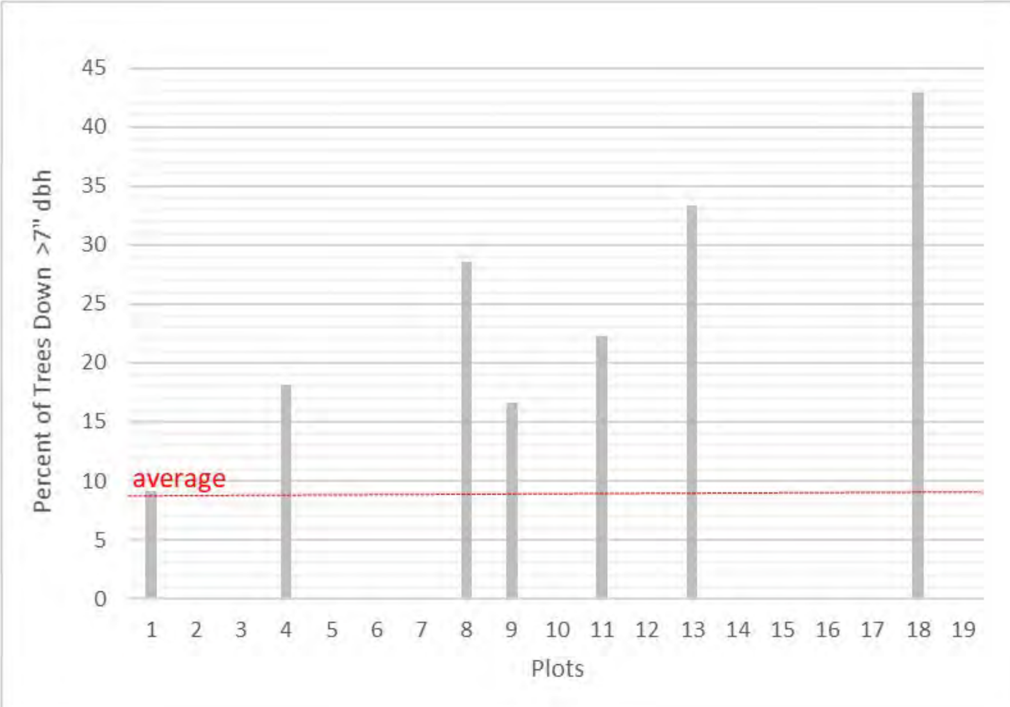

Figure 77. Percent of trees (>7" dbh) down in all plots at St. George Island State Park.

Natural Community	**Canopy Height**	**Canopy Cover**	**Subcanopy Height**	**Subcanopy Cover**	**Pine Basal Area**
beach dune	7.5	0.2	22.5	0.2	2.0
scrubby flatwoods	40.5	10.9	16.5	3.3	26.0
average	**28.1**	**6.9**	**17.7**	**2.1**	**14.0**
	Fine Fuels	**Medium Fuels**	**Heavy Fuels**	**Graminoid Cover**	**Total Shrub Cover**
beach dune	1.0	0.4	0.4	3.3	2.6
scrubby flatwoods	1.2	1.6	1.2	0.6	40.5
average	**1.1**	**1.0**	**0.8**	**2.0**	**21.6**

Figure 78. *Data summary of plots. . Height measurements in feet, cover in percentages, pine basal area in ft^2/acre. Ranked fuels low is 1, medium is 2, and 3 is high.*

Another significant and challenging effect of Hurricane Michael at SGISP was storm surge, which flattened most of the primary dunes in the park and deposited up to 5 feet of sand on the main park road. At the time of this survey the road had been cleared and was functional. The sand removed from the road was piled on the south side of the road and will likely serve as the start of several new primary dunes. The campground, youth camp area, and beach pavilion all suffered some damage.

At the time of the field assessment, tree removal was already completed throughout the campground and youth camp areas, focusing on the immediate needs of clearing trees on and hanging over roads and structures (Figure 79). Storm debris remains heavy in some low areas away from the roads and facilities.

Figure 79. Trees removed around the campground.

The two beach pavilion and bathroom complexes were not evaluated during the field survey but the land manager stated that structural damage had occurred during the storm, likely from both surge and wind. The dune landscape around these day-use areas is heavily changed because many of the primary dunes were washed out (Figure 80). Beach crossovers were seen to have structural damage (Figure 81).

Figure 80. Beach day-use area in SG-12 post-storm.

Figure 81. Beach crossover damaged by the storm in Zone SG-12.

Pine habitats (scrubby and wet flatwoods)

Pine habitats at SGISP are dominated by scrubby, mesic, and wet flatwoods. All of these habitats historically have an open canopy of slash pine (*Pinus elliottii,* because of the parks proximity to the coast) and a predominantly herbaceous understory featuring, most notably, wiregrass (*Aristida stricta*). All of these pine dominated habitats require fire (suggested FRI 2-4 years for mesic and wet flatwoods, 5-15 years for scrubby flatwoods; FNAI 2010). Approximately 30% of the park was historically dominated by these pine uplands in a mosaic where scrubby flatwoods occupies the highest elevations with dry sandy soils and the wet flatwoods occupies the lower, sometimes inundated, areas where cabbage palm (*Sabal palmetto*) and saltmeadow cordgrass (*Spartina patens*) are dominant. The pine uplands at SGISP are, for the most part, in fair to good condition with an older mature canopy of slash pine mostly low but sometimes dense shrub cover, and an herbaceous groundcover. No canopy damage from wind was observed in most areas visited (Figures 82 - 84). Many of the slash pines are yellowing, a likely result of salt water. These trees will likely be fine with time.

Because of the significant storm surge that washed over the park, a heavy wrack of debris was observed in low spots throughout the surveyed areas (at the base of dunes, in scrubby and wet flatwoods, and marsh). This debris is largely plant material but also contains trash (both small and large pieces) that washed up in the storm and settled in low lying areas when the water receded (Figures 85 and 86). The manager stated that most of the larger pieces of trash (e.g., appliances) had been removed. The thicker areas of accumulated plant material (as seen in Figure 85) will likely locally increase salt in the soil and bury existing plants which could result in small scale, isolated vegetation damage. In some specific areas, active restoration efforts may be necessary such as replanting with native groundcover species. However, in most cases, reintroducing fire as soon as feasible is the only restoration pine forests on SGISP recommended.

Figure 82. Wet flatwoods in Zone SG-02 as seen from a tall tertiary dune with no apparent wind damage to the canopy. Many of the slash pines are yellowing, a likely result of salt water.

Figure 83. Scrubby flatwoods with no canopy damage.

Figure 84. Scrubby flatwoods with light damage from wind.

Figure 85. Heavy storm debris deposited on a wet flatwoods very near the bay in Zone SG-03.

Figure 86. Heavy debris and portion of boardwalk accumulated in a wet flatwoods in Zone SG-14.

Beach Dune

SGISP boasts some of the tallest and most extensive beach dunes in the Florida panhandle. Beach dunes are found on high ridges running parallel to the shoreline and are often found in a series of ridges and swales (coastal grassland) paralleling the beach and adjacent to scrub or flatwoods on their inland side. Beach dunes vary in their vegetation cover from mostly open sand with herbaceous species such as seaoats (*Uniola paniculata*) often seen on primary dunes to more shrubby species such as Florida rosemary (*Ceratiola ericoides*), woody goldenrod (*Chrysoma pauciflosculosa*), sand live oak (*Quercus geminata*) and sand pine (*Pinus clausa*) as dunes that are more established and/or further from the coast (i.e., secondary and tertiary dunes).

The dune system at SGISP has variable damage. The primary dunes on the east and south sides of the main park road were severely damaged. Some are heavily eroded or sheared off on the ocean side and some have been completely removed, leaving a wide flat sand surface where the dunes once stood (Figures 87 and 88). In this case, much of the sand was deposited on the vegetated, landward side of the dunes (coastal grassland) and on the park road. Some of the highest dunes observed during the field survey, on the north and west side of the main park road, appeared fairly intact but have light to moderate erosion (Figure 89). Heavy storm debris was observed at the base of one tertiary dune in Zone SG-01, a result of the storm surge that was blocked by the extremely tall dune (Figure 90). This tertiary dune did experience some sand deposition as well; it remains in fairly good condition.

Figure 87. Park road with flattened dune system on both sides.

Figure 88. Sheared off primary dune.

Figure 89. Tertiary dune with coastal grassland in the foreground.

Figure 90. Tertiary dune with heavy debris at its base and some sand accumulation in Zone SG-01.

As stated in the management plan for St. Joe Peninsula State Park, "The beach dune community is a dynamic system and is constantly changing depending on the stage of recovery after storm impacts." The recovery of these dunes will simply take time.

Coastal Grassland

Coastal grassland is a flatland located behind beach dune with stable sand substrate and mostly herbaceous vegetation dominated by salt-tolerant herbs such as sea oats (*Uniola paniculata*) and bitter panicgrass (*Panicum amarum*) (Figure 91). Coastal grasslands are heavily influenced by storms, and fire is rare. The coastal grasslands at SGISP were observed to have several kinds of damage as a result of Hurricane Michael. A few small areas where young slash pines had colonized, such as in Zone SG-12, have a heavy litter layer following the death of the trees combined with some storm debris (Figure 92). Further northeast, in Zone SG-14, heavy sand deposition was observed, partially burying the grasses and sedges (Figures 93 and 94). When storm waves breach the dune and spread sand over a coastal grassland, a beach dune community may recolonize at first (FNAI 2010). Fertilization from dead organic material washed up helps to speed plant growth and the recolonization process. Once a new foredune ridge builds up above the beach and inhibits further sand movement behind the ridge, other herbaceous species can colonize forming a new coastal grassland behind the dune (FNAI 2010).

Figure 91. Coastal grassland beyond beach dune.

Figure 92. Slash pine in coastal grassland that were killed by salt water.

Figure 93. Coastal grassland with sand deposition from adjacent dune.

Figure 94. Graminoids in a coastal grassland in Zone SG-14 partially buried by sand from nearby washed out dune.

Task 3: Restoration Evaluation

Restoration options to consider include: prescribed burning, native planting, native seeding, mechanical removal of vegetation, and chemical control of exotic species (could be conducted in all areas with hazard tree removal).

Recommendations Based on Historic and Current Conditions

Historic aerials were not available for St. George Island State Park. However, historic conditions are likely similar to current conditions aside from areas cleared for park infrastructure and dunes which may have shifted therefore there are no further recommendations based on historic photos.

T.H. Stone Memorial St. Joseph Peninsula State Park

Management Context Related to Restoration Activities

The DRP's philosophy of resource management places primary emphasis on restoring and maintaining, to the degree possible, the natural processes that shaped the structure, function and species composition of Florida's diverse natural communities as they occurred in the original domain. The primary management tools for restoration include the application of such measures as prescribed burning, exotic species removal, imperiled species management, cultural resource management, and restoration of natural conditions. Specific examples that would qualify as natural communities' restoration, requiring annual restoration plans, include large mitigation projects, large-scale hardwood removal and timbering activities, roller-chopping, and other large-scale vegetative modifications. During the development of the 2014 management plan, an analysis was made regarding the feasibility of timber management activities in the park; it was determined that the primary management objectives of the unit could be met without conducting timber management activities.

The following park goals express DRP's long-term intent in managing the state park.

1. Provide administrative support for all park functions.
2. Protect water quality and quantity in the park, restore hydrology to the extent feasible and maintain the restored condition.
3. Restore and maintain the natural communities/habitats of the park. Maintain, improve, or restore imperiled species populations and habitats in the park.
4. Remove exotic and invasive plants and animals from the park and conduct needed maintenance-control.
5. Protect, preserve, and maintain the cultural resources of the park.
6. Provide public access and recreational opportunities in the park.
7. Develop and maintain the capital facilities and infrastructure necessary to meet the goals and objectives of this management plan.

Task 1: Rapid Assessment of Timber Salvage Options

Because the damage was relatively minor and/or small-scale, there is no need to assess timber options. Park managers have already removed timber from campground and other park infrastructure. All units were assessed using the RRAM tool (Figure 1) however, none were identified to be evaluated for potential timber operations.

Task 2: Rapid Damage Assessment

Rapid damage assessment was conducted at two scales: using remote sensing and on the ground with plots and visual observations. First, damage was assessed through remote sensing using normalized difference vegetation index (NDVI). NDVI is a simple graphical indicator that assesses whether the target being observed contains live green vegetation; this has been used effectively to assess storm damage (Wang et al. 2010). Using MODIS satellite imagery, FNAI determined the difference in NDVI (dNDVI) from October 2017 to October 2018 (Figure 95) Some factors which need to be considered when interpreting

NDVI readings are: 1) areas dominated by grass, standing water, or impervious surface may alter results; 2) other landuse changes within the last year (e.g. fire, logging, etc.); 3) actual damage to deciduous trees could be overestimated and 4) trees, especially pines, may not have fully browned. Next, we applied the values to natural communities and park boundaries MODIS satellite imagery provides NDVI values at a 250x250 meter. dNDVI values were assigned to damage class bins which were created using post storm imagery and U.S. Forest Service hurricane fuels assessment categories (Figure 96).

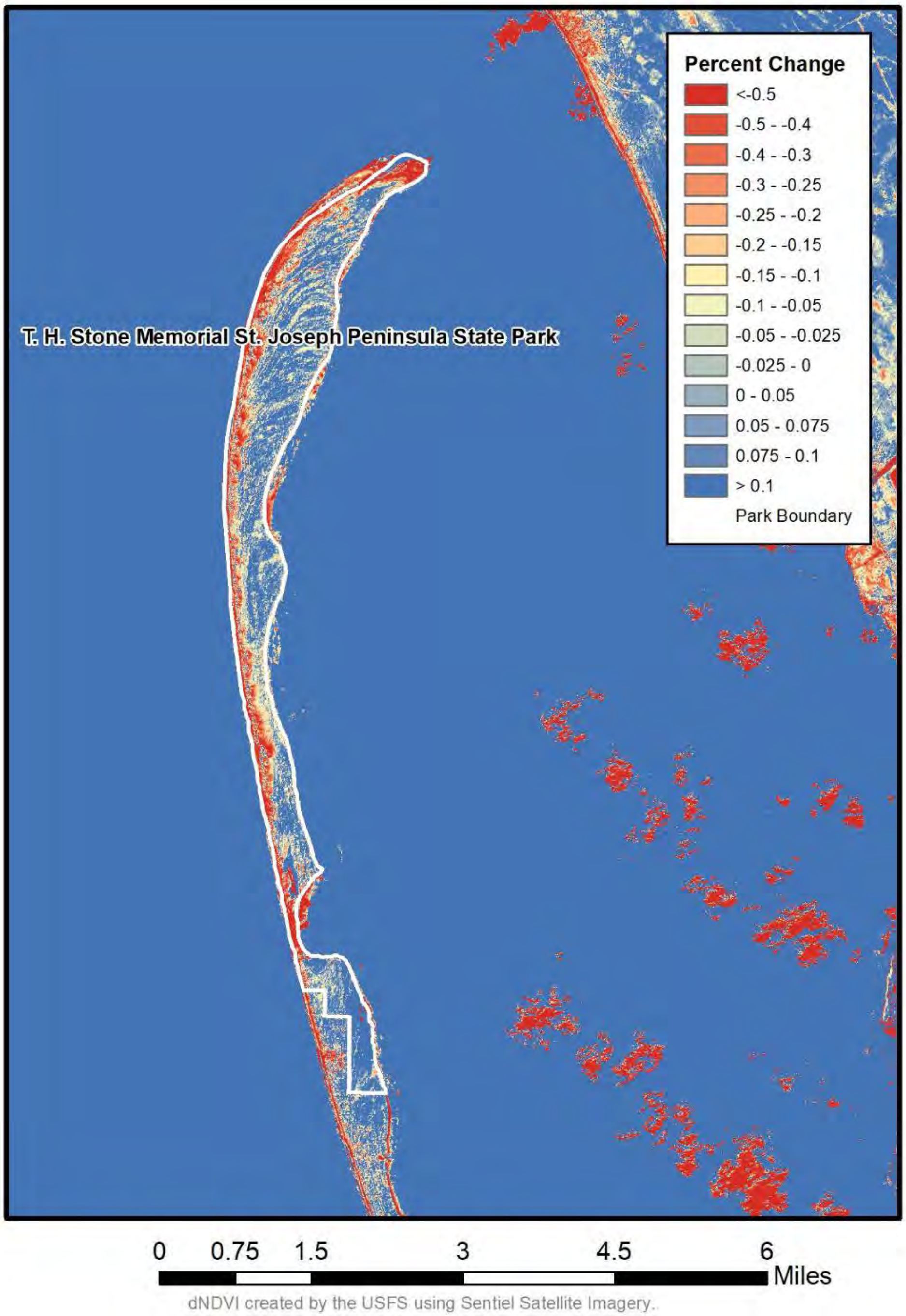

Figure 95. The dNDVI shows relatively low change values indicating light to moderate damage which is consistent with on the ground inspections.

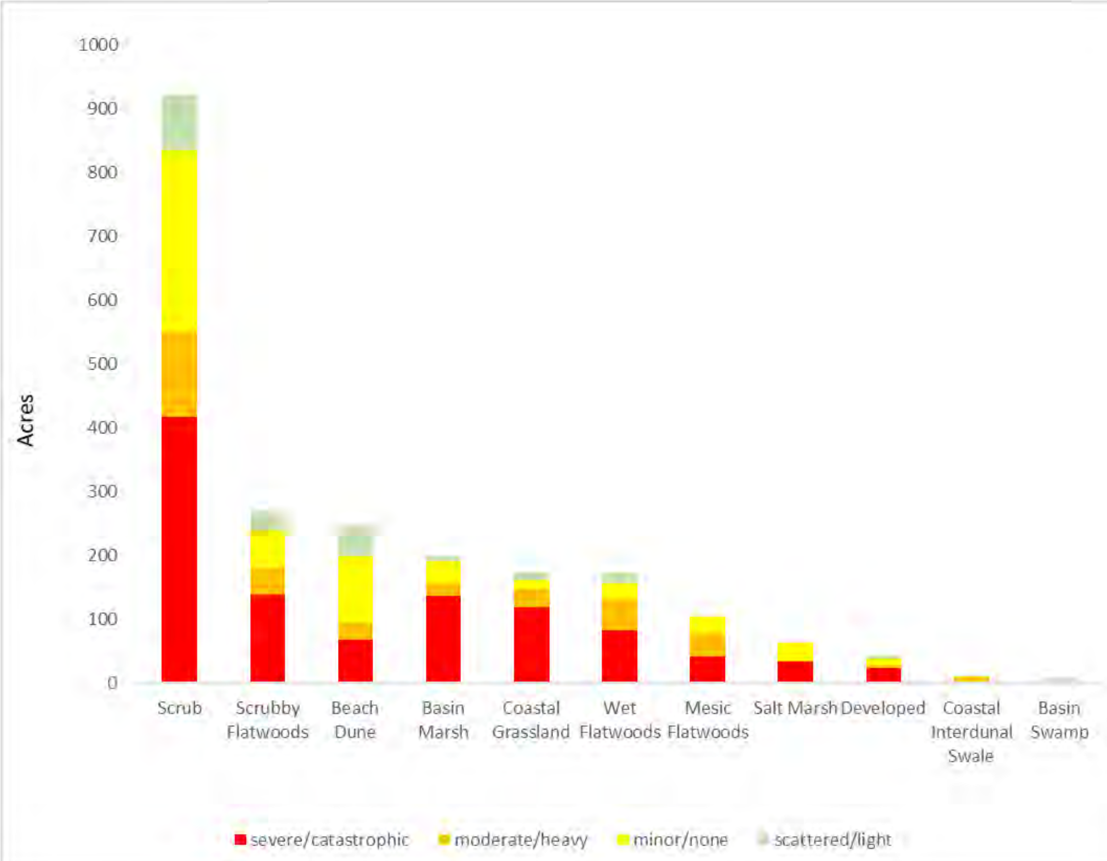

Figure 96. dNDVI Estimated Acres by Damage Class.

FNAI scientists surveyed accessible areas on foot and vehicle to evaluate aspects of the habitat conditions that cannot be observed via aerial photography. We estimated fuels and other forest structure metrics (Figures 97 and 98) using standard FNAI natural community plots (see Appendix H data form and category definitions) with photo points collected at the center of each plot (See Appendix F). Because access and time was limited, we conducted non-random assessment plots. The number of plots was determined by the range of variability found within each natural community represented. We also limited the scope of our on the ground assessments to natural communities which would have higher restoration potential (e.g. where active management is generally more appropriate). However, despite having less plots, results were similar under-sampled communities and seem representative of visual inspections on the ground.

A field assessment was completed on January 31, 2019. Most, if not all, of the park was overwashed with a significant storm surge which heavily eroded dunes (especially primary dunes), damaged and destroyed structures, deposited heavy layers of storm debris (plant material, trash, and pieces of damaged structures from the park), and caused tree death (sand pine (*Pinus clausa*) and sand live oak (*Quercus geminata*)) because of salt water damage.

The most significant change to pine dominated natural communities as a result of the storm is in the form of tree damage. Generally, the canopies of all habitats that were observed during the short field assessment were damaged. The damaged trees are both blown down from the roots, the stem broken forming “A frames”, or the trees are standing dead from salt water influence. Damage was variable, from light to severe with downed trees occasionally observed ranging from 0 to 100% removal in our plots. On average, the damage was 56% (Figure 97). Damage was generally lighter in the flatwoods areas and heavier in scrub areas dominated by sand pine. Downed and dead trees create increased fuel loads as well as increased sunlight to the ground layer. Increased sunlight to forest floor may increase herbaceous plant diversity and abundance. There is also fine fuel present. Increases to fine fuels from storm damage will increase the risk of wildfire under dry conditions but also allow for better fuel continuity for prescribed burns done under more favorable conditions. A table below lists other variables measured in the plots (Figure 98).

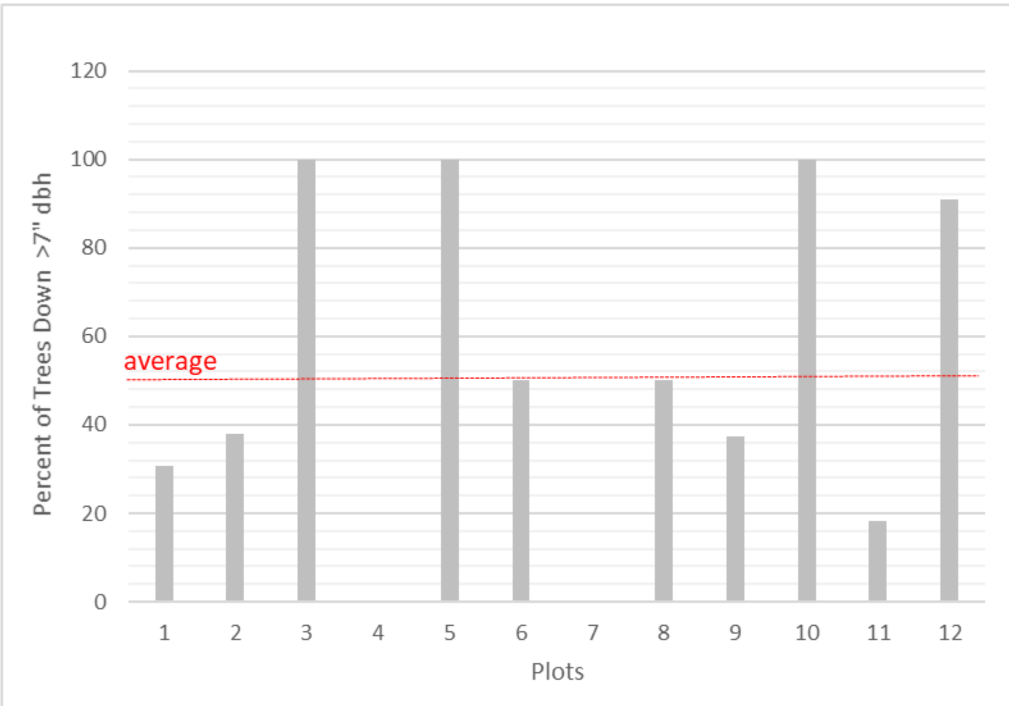

Figure 97. *Percent of trees (>7” dbh) down in all plots at St. Joe Peninsula State Park.*

Natural Community	Canopy Height	Canopy Cover	Subcanopy Height	Subcanopy Cover	Pine Basal Area
beach dune	0.0	0.0	0.0	0.0	0.0
mesic flatwoods	35.0	8.2	12.9	1.1	15.0
scrub	22.5	1.3	10.5	1.3	0.0
scrubby flatwoods	22.5	0.5	10.5	0.3	5.0
Average	**27.8**	**4.8**	**12.2**	**0.9**	**7.8**
	Fine Fuels	**Medium Fuels**	**Heavy Fuels**	**Graminoid Cover**	**Total Shrub Cover**
beach dune	1.0	1.0	1.0	0.5	0.0
mesic flatwoods	2.0	1.8	1.7	8.4	44.2
scrub	2.0	2.5	2.5	0.0	36.5
scrubby flatwoods	2.5	3.0	3.0	0.3	25.5
Average	**2**	**2.1**	**2.0**	**4.9**	**35.4**

Figure 98. Data summary of plots. . Height measurements in feet, cover in percentages, pine basal area in ft^2/acre. Ranked fuels low is 1, medium is 2, and 3 is high.

Another significant and challenging effect of Hurricane Michael is the newly formed island breach created by the storm surge, leaving the northern ¾ of the park an island and only accessible by boat

(Figures 99 and 100). This poses the most challenging obstacle to reopening the majority of the park as well as hurricane cleanup and restoration. The campgrounds, cabins, picnic area, staff housing and most of the parks day use areas are all north of the breach. Solutions to this are being considered by the Park Service and will significantly affect all future restoration efforts north of the breach.

At the time of the field assessment, tree removal was already completed in the southern portion of the park (south of the breach), focusing on the immediate needs of clearing trees on and hanging over roads, structures, and visitor safety areas (parking lots and beach crossovers). The park roads and facilities (south of the breach) were early priorities because of access to the park for visitors and structural dangers where park staff are housed and work. All timber and storm debris that had impacted the main road leading to Eagle Harbor (parking area, dock, and beach crossover) has been removed. Storm debris remains heavy in low areas away from the roads and facilities and even large items that washed up can still be seen in the flatwoods (Figure 101). This portion of the park is open to visitors with access to the Eagle Harbor dock and beach crossing directly to the east.

Figure 99. Newly formed breach at Eagle Harbor in St. Joe Peninsula State Park. Imagery from 2016 and October 13, 2018 (post-storm).

Figure 100. The newly formed breach looking north.

Figure 101. Large items that washed up remain in the flatwoods just south of Eagle Harbor.

North of the breach, the cabins, staff residences, campgrounds, boardwalks, and picnic areas all suffered significant structural damage from wind and/or water impacts (Figure 102). The Shady Pines Campground has tree damage, structural damage (pavilion, see Figure 102), and significant sand deposition from a nearby washed out dune (Figure 103). The ~500 m boardwalk that previously stretched between the Shady Pines and Gulf Breeze Campgrounds was washed out and pieces of it are deposited throughout the area in the flatwoods and marsh (Figure 103). Trees are still remaining on roads (Figure 104) and picnic tables and debris are widely deposited. The Gulf Breeze Campground and picnic area were not visited during the site visit but according to the park manager both were heavily impacted. The cabins were structurally impacted by storm surge flooding and currently have damaged trees around them. The boardwalk leading to beach access on the southern edge of the wilderness area was also washed out due to storm surge flooding (Figure 105).

Figure 102. Significant damage to pavilion in Shady Pine campground.

Figure 103. Sand deposition from nearby washed out dune and washed up portion of boardwalk in the Shady Pine campground.

Figure 104. Trees remaining on the road leading to the Shady Breeze Campground.

Figure 105. Boardwalk leading to beach access on the southern edge of the wilderness area.

Pine habitats (scrubby, mesic, and wet flatwoods)

Pine habitats at SJSP are dominated by scrubby, mesic, and wet flatwoods. All of these habitats historically have an open canopy of slash pine (*Pinus elliottii,* because of the parks proximity to the coast) and a dominantly herbaceous understory. All of these pine dominated habitats require fire (suggested FRI 2-4 years for mesic and wet flatwoods, 5-15 years for scrubby flatwoods; FNAI 2010). Approximately 22% of the park was historically dominated by these pine uplands in a mosaic where scrubby flatwoods occupied the highest elevations with dry sandy soils, the wet flatwoods occupied the lower, sometimes inundated, areas where cabbage palm (*Sabal palmetto*) and sawgrass (*Cladium jamaicense*) and mesic flatwoods with saw palmetto (*Serenoa repens*) occurred in the intermediate areas between the two. The pine habitats at FWSP are, for the most part, in fair to good condition with an older mature canopy of slash pine, mostly low but dense shrub cover, and a moderate presence of herbaceous groundcover. Minor canopy was observed in most areas visited after the storm (Figures 106), with several small areas where heavy (Figure 107) to moderate (Figure 108) damage was observed.

Figure 106. Minor canopy damage in high quality Scrubby flatwoods in Zone SJ-09.

Figure 107. Heavy canopy damage in scrubby flatwoods in Zone SJ-10.

Figure 108. Moderate canopy damage observed in mesic flatwoods in Zone SJ-05A.

All of the wet flatwoods and much of the mesic flatwoods were inundated at the time of the survey and only minor canopy damage was observed in the areas that were surveyed (Figure 109). Because of the significant storm surge (~15 feet according to the park manager) a heavy wrack of debris was observed in low spots (mesic and wet flatwoods and marsh) across the entire park. This debris is largely organic material but also contains trash (both small and large pieces) that washed up in the storm and settled in low lying areas when the water receded (Figures 110 and 111). The thicker areas of accumulated tidal debris (as seen in Figure 109, approximately 2-3 feet thick) is expected to locally increase salt in the soil and bury existing plants which could result in small scale, isolated damage. In some specific areas, active restoration efforts in these areas may be necessary such as replanting with native groundcover species. However, in most cases, reintroducing fire as soon as feasible is the only further restoration pine the forests on SJSP which is required to attain desired future conditions and mitigate storm related damage.

Figure 109. Wet flatwoods with minor damage.

Figure 110. Heavy storm debris in scrubby flatwoods in Zone SJ-10.

Figure 111. Heavy storm debris in scrubby flatwoods with a portion of a boardwalk in Zone SJ-10.

Scrub

Scrub occurs on the driest ridge crests and occupies approximately 36% of SJSP in the driest areas on the landward side of the dunes. Most notably is the 863 acre contiguous scrub in the northern portion of the park which contains the FNAI recognized reference site for scrub in 2009 (FNAI 2009). Scrub at SJSP is characterized by a canopy of sand pine (*Pinus clausa*), a dense shrub layer of sand live oak (*Quercus geminata*), myrtle oak (*Quercus myrtifolia*), and Florida rosemary (*Ceratiola ericoides*). Other species of note include false rosemary (*Conradina canescens*) and woody goldenrod (*Chrysoma pauciflosculosa*).

Canopy damage observed during the field assessment in scrub was variable from almost complete loss to moderate (Figures 112 and 113). The canopy and shrub layers in many scrub stands visited had major damage from salt water exposure or inundation. Sand pine needles and sand live oak leaves were salt burned.. The sand pine needles were fully browned and likely dead at the time of the field survey. Damaged sand pines with fully browned needles will likely not regenerate but the sand live oaks were seen resprouting (Figure 114). This additional fuel load is expected to increase flammability in areas where extensive damage is present. Reintroducing fire as soon as feasible is the only further restoration the scrub on SJSP needs, which is required to attain desired future conditions and mitigate storm related damage.

Figure 112. An example of scrub with a high percentage of canopy and shrub death in Zone SJ-10.

Figure 113. An example of scrub with a lower percentage of canopy and shrub death in Zone SJ-10.

Figure 114. Resprouting sand live oak.

Beach Dune

SJSP boasts some of the tallest and most magnificent beach dunes in the Florida panhandle reaching 35 feet high (DEP 2014). Beach dunes are found on high ridges running parallel to the shoreline and are often found in a series of ridges and swales (coastal grassland) paralleling the beach and adjacent to scrub or flatwoods inland. Beach dunes vary in their vegetation cover from mostly open sand with herbaceous species such as seaoats (*Uniola paniculata*) often seen on primary dunes to more shrubby species such as Florida rosemary (*Ceratiola ericoides*), woody goldenrod (*Chrysoma pauciflosculosa*), sand live oak (*Quercus geminata*) and sand pine (*Pinus clausa*).

The dune system at SJSP has variable damage. Some of the highest dunes observed during the field survey appeared fairly intact from the landward side (Figure 115) but are sheared off on the ocean side (Figure 116) and some have been completely removed by the force of the wind and water (Figures 117 and 118), leaving a wide flat sand surface where the dunes once stood. In this case, much of the sand was deposited on the vegetated landward side of the dune (i.e., flatwoods).

Figure 115. Tall dune seen from the flatwoods looking east in Zone SJ-09.

Figure 116. Sheared off dune in Zone SJ-09.

Figure 117. Area where the dune blew out and the wind actually caused a deep pool of water near where the dune use to be.

Figure 118. Area where dune was washed out, vegetation seen here used to be on the back side of the dune.

As the SJSP management plan states, “The beach dune community is a dynamic system and is constantly changing depending on the stage of recovery after storm impacts.” The recovery of these dunes will simply take time.

Task 3: Restoration Evaluation

Restoration options to consider include: prescribed burning, native planting, native seeding, mechanical removal of vegetation, and chemical control of exotic species (could be conducted in all areas with hazard tree removal). The purpose here is to outline what actions can be taken in the near term.

Recommendations Based on Historic and Current Conditions

Historic aerials were not available for St. Joe Peninsula State Park. However, historic conditions are likely similar to current conditions aside from areas cleared for park infrastructure and natural shifting of dunes. There are no further recommendations based on historic photos.

St. Andrew's State Park

Management Context Related to Restoration Activities

St. Andrews State Park (SASP) was acquired to provide resource-based public outdoor recreation opportunities while ensuring the conservation and protection of valuable natural resources, including imperiled species and unique ecosystems (DEP 2016b). The park protects one of the largest segments of undeveloped barrier island along the central Florida Panhandle. Over four miles of pristine beaches along Shell Island and several miles of shoreline along St. Andrew Bay provide habitat for a number of imperiled species including the Gulf saltmarsh snake (*Nerodia clarkii clarkii*), least tern (*Sternula antillarum*), snowy plover (*Charadrius nivosus*), Choctawhatchee beach mouse (*Peromyscus polionotus allophrys*), and nesting opportunities for many sea turtles. In addition, the park protects significant and exemplary natural community types, including estuarine tidal marsh, freshwater depression marsh, scrub, maritime hammock, beach dune, and rare coastal dune lakes.

The DRP's philosophy of resource management is natural systems management. Primary emphasis is placed on restoring and maintaining, to the degree possible, the natural processes that shaped the structure, function and species composition of Florida's diverse natural communities as they occurred in the original domain. The primary restoration tools Identified for the park include measures as prescribed burning, exotic species removal, imperiled species management, cultural resource management and restoration of natural conditions. The park's management plan (2016b) determined that the primary management objectives of the unit could be met without conducting timber management activities for this management plan cycle.

According to the 2016 management plan, the following park goals express DRP's long-term intent in managing the state park:

1. Provide administrative support for all park functions.
2. Protect water quality and quantity in the park, restore hydrology to the extent feasible and maintain the restored condition.
3. Restore and maintain the natural communities/habitats of the park.
4. Maintain, improve or restore imperiled species populations and habitats in the park.
5. Remove exotic and invasive plants and animals from the park and conduct needed maintenance-control.
6. Protect, preserve and maintain the cultural resources of the park.
7. Provide public access and recreational opportunities in the park.
8. Develop and maintain the capital facilities and infrastructure necessary to meet the goals and objectives of this management plan.

Task 1: Rapid Assessment of Timber Salvage Options

Because the damage was relatively minor and/or small-scale, there is no need to assess timber options. Park managers have already removed timber from campground and other park infrastructure. All units were assessed using the RRAM tool (Figure 1) however, none were identified to be evaluated for potential timber operations.

Task 2: Rapid Damage Assessment

Rapid damage assessment was conducted at two scales: using remote sensing and on the ground with plots and visual observations. First, damage was assessed through remote sensing using normalized difference vegetation index (NDVI). NDVI is a simple graphical indicator that assesses whether the target being observed contains live green vegetation; this has been used effectively to assess storm damage (Wang et al. 2010). Using MODIS satellite imagery, FNAI determined the difference in NDVI (dNDVI) from October 2017 to October 2018 (Figure 119) Some factors which need to be considered when interpreting NDVI readings are: 1) areas dominated by grass, standing water, or impervious surface may alter results; 2) other landuse changes within the last year (e.g. fire, logging, etc.); 3) actual damage to deciduous trees could be overestimated and 4) trees, especially pines, may not have fully browned. Next, we applied the values to natural communities and park boundaries MODIS satellite imagery provides NDVI values at a 250x250 meter. dNDVI values were assigned to damage class bins which were created using post storm imagery and U.S. Forest Service hurricane fuels assessment categories (Figure 120).

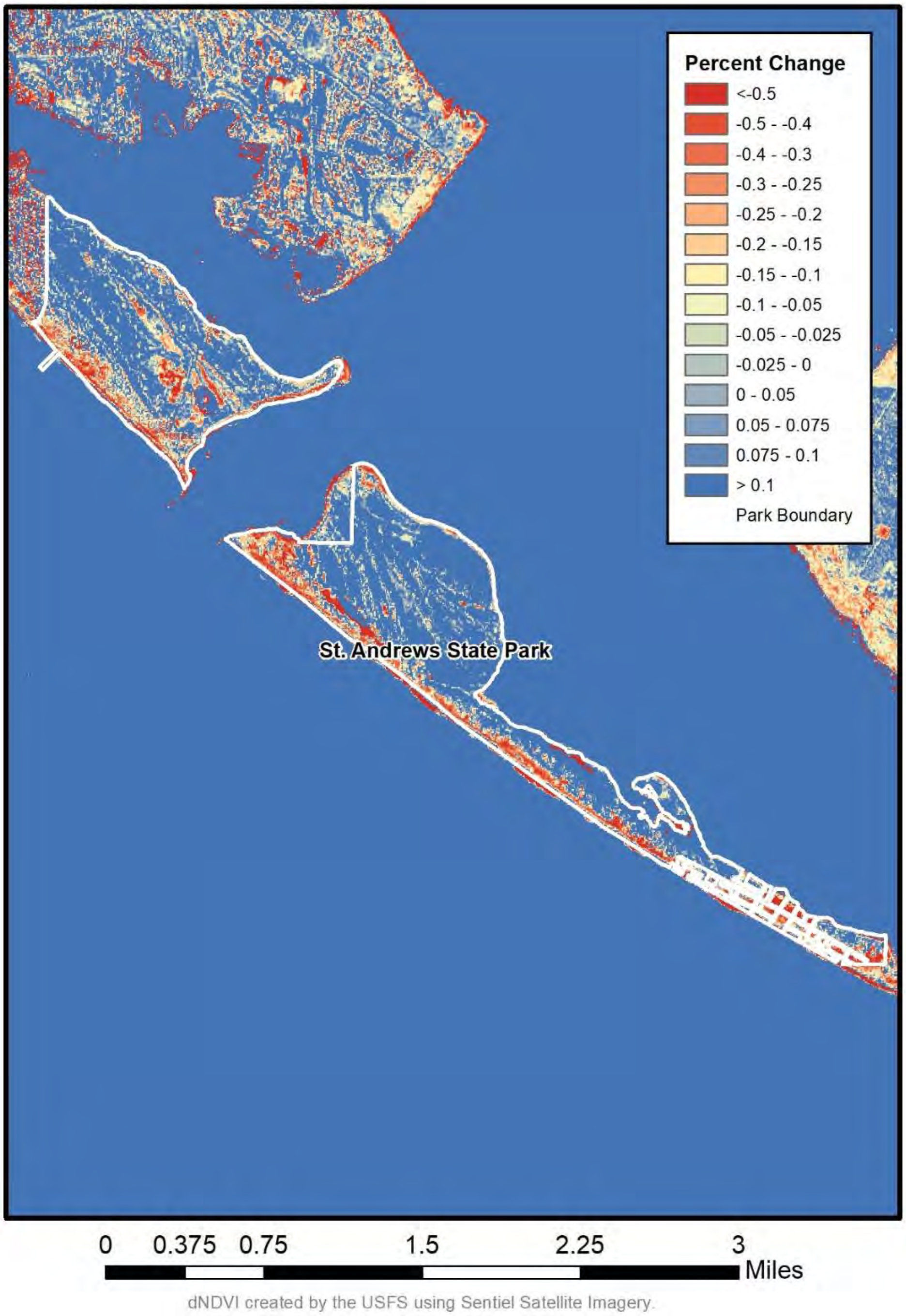

Figure 119. The dNDVI shows relatively low change values indicating light to moderate damage which is consistent with on the ground inspections.

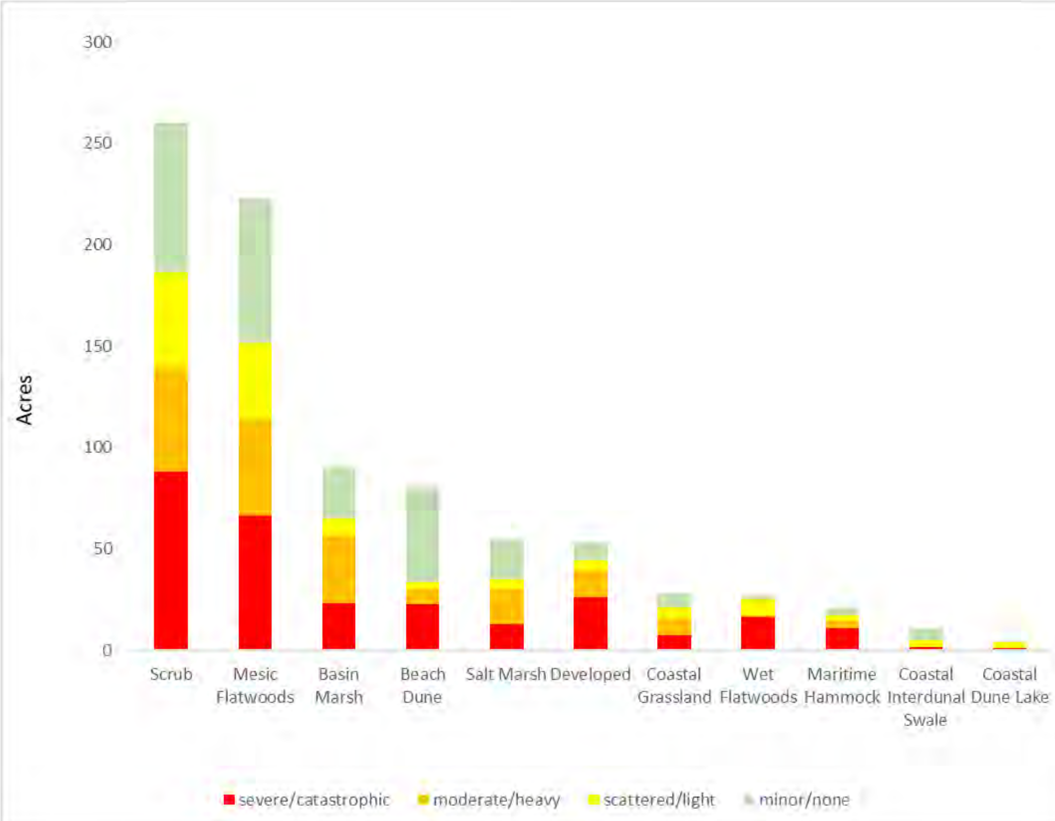

Figure 120. dNDVI Estimated Acres by Damage Class.

FNAI scientists surveyed accessible areas on foot and vehicle to evaluate aspects of the habitat conditions that cannot be observed via aerial photography. We estimated fuels and other forest structure metrics (Figures 121 and 122) using standard FNAI natural community plots (see Appendix H data form and category definitions) with photo points collected at the center of each plot (See Appendix F). Because access and time was limited, we conducted non-random assessment plots. The number of plots was determined by the range of variability found within each natural community represented. We also limited the scope of our on the ground assessments to natural communities which would have higher restoration potential (e.g. where active management is generally more appropriate). However, despite having less plots, results were similar under-sampled communities and seem representative of visual inspections on the ground. A table below lists other variables measured in the plots (Figure 122).

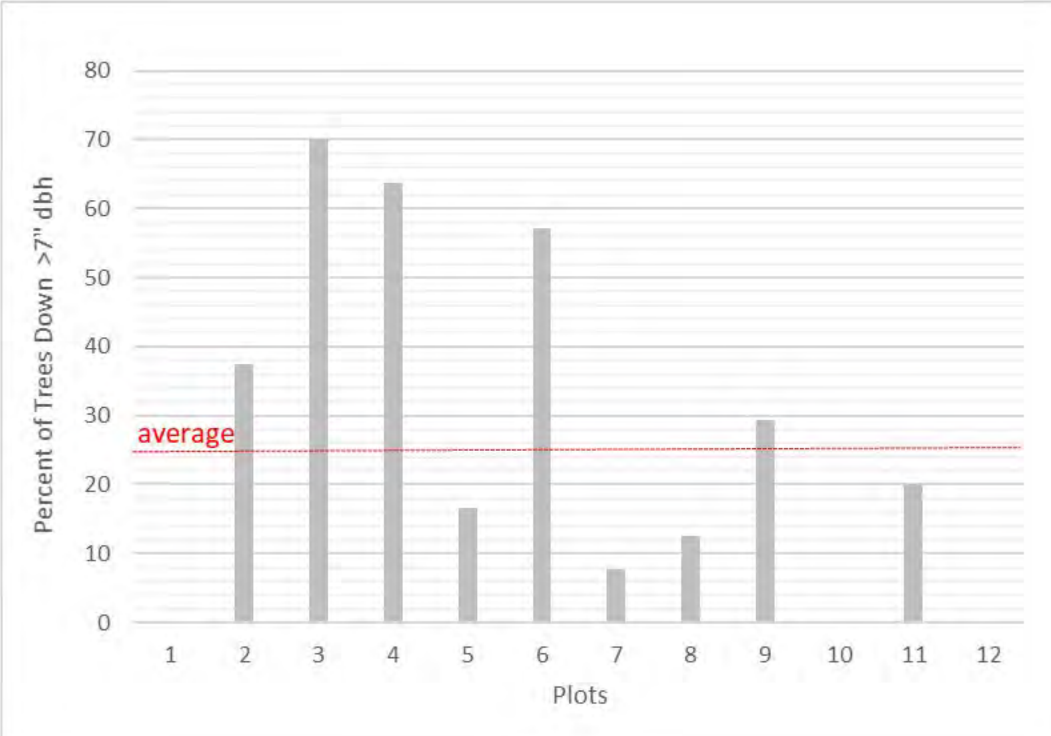

Figure 121. *Percent of trees (>7" dbh) down in all plots at St. Andrews State Park.*

Natural Community	Canopy Height	Canopy Cover	Subcanopy Height	Subcanopy Cover	Pine Basal Area
beach dune	0.0	0.0	0.0	0.0	0.0
mesic flatwoods	48.8	11.5	22.5	1.0	60.0
scrub	22.5	5.9	10.5	12.9	20.0
Average	**35.6**	**8.7**	**15.3**	**7.8**	**32.0**
	Fine Fuels	**Medium Fuels**	**Heavy Fuels**	**Graminoid Cover**	**Total Shrub Cover**
beach dune	0.5	0.0	0.0	1.5	20.5
mesic flatwoods	2.5	2.3	2.0	10.4	10.5
scrub	2.5	2.3	2.3	0.0	30.5
Average	**2.1**	**1.8**	**1.7**	**4.45**	**20.5**

Figure 122. Data summary of plots. Height measurements in feet, cover in percentages, pine basal area in ft^2/acre. Ranked fuels low is 1, medium is 2, and 3 is high.

A field assessment was completed on February 8, 2019. Much of the park was overwashed with a significant storm surge which heavily eroded dunes (especially primary dunes), damaged structures, deposited of storm debris (plant material and trash), and caused some tree mortality.

The most significant change to natural communities as a result of the storm was tree damage. Generally, the canopies of all habitats that were observed during the short field assessment experienced some damage. The damaged trees are blown down from the roots, the stem broken forming "A frames", or the trees are standing dead from salt water influence. Damage was generally light in most places; percent downed trees observed ranged from 0 to 70% in our plots. On average, the damage was light (~25%) (Figure 120). Damage was generally heavy in scrub areas dominated by sand pine. Downed and dead trees have increased fuel loads as well as increased sunlight to the ground layer. Increased sunlight to forest floor may increase herbaceous plant diversity and abundance but also will increase the probability of ignition under most conditions due to the increase in fine fuels. Increases to fine fuels from both damage will increase the risk of wildfire under dry conditions but also allow for better fuel continuity for prescribed burns done under more favorable conditions.

Another significant and challenging effect of Hurricane Michael at SASP is from storm surge, which affected most of the primary dunes in the park. At the time of this survey, debris and other hazards to the main park roads had been mitigated and the roads were fully functional. Storm debris remains heavy in some low areas away from the roads and facilities. All facilities seemed functional at the time of survey.

Scrub

Scrub occurs on the driest ridge crests and occupies approximately 29% of SASP in the driest areas on the landward side of the dunes. Scrub at SASP is characterized by a canopy of sand pine (*Pinus clausa*), a dense shrub layer of sand live oak (*Quercus geminata*), myrtle oak (*Quercus myrtifolia*), and Florida rosemary (*Ceratiola ericoides*). Other species of note include false rosemary (Conradina canescens) and woody goldenrod (*Chrysoma pauciflosculosa*).

Canopy damage observed during the field assessment in scrub was variable from severe to light (Figures 123-125). The canopy and shrub layers in many scrub stands that were visited had major damage due to salt water. Decadent, older growth sand pines had almost 100% mortality in exposed areas. The sand pine needles were fully browned and likely dead at the time of the field survey. Damaged sand pines with fully browned needles will likely not regenerate but the sand live oaks are likely to resprout. This additional fuel load is expected to increase flammability in areas where extensive damage is present. Reintroducing fire as soon as feasible is the only further restoration the scrub on SASP needs, which is required to attain desired future conditions and mitigate storm related damage.

Figure 123. Light damage to Scrub

Figure 124. Moderate damage to scrub.

Figure 125. Heavy damage to scrub.

Pine habitats (scrubby and wet flatwoods)

Pine habitats at SASP are dominated by scrubby, mesic, and wet flatwoods. All of these habitats historically have an open canopy of slash pine (*Pinus elliottii,* because of the parks proximity to the coast) and a dominantly herbaceous understory featuring, most notably, wiregrass (*Aristida stricta*). All of these pine dominated habitats require fire (suggested FRI 2-4 years for wet flatwoods, 5-15 years for scrubby flatwoods; FNAI 2010). Approximately 28% of the park is dominated by these pine uplands in a mosaic where scrub and scrubby flatwoods occupies the highest elevations with dry sandy soils and wet flatwoods occupies the lower, sometimes inundated, areas where palmetto and *Andropogon* species are dominant. The pine uplands at SASP are, for the most part, in fair to good condition with an older mature canopy of slash pine mostly low but sometimes dense shrub cover, and an herbaceous groundcover. Moderate to heavy canopy damage is common on the bayside and is relatively minor on the ocean side (Figures 126 and 127). Many of the slash pines are yellowing, a likely result of salt water (Figure 128). These trees may recover depending on the rainfall and resultant salinity levels in the upcoming months.

Figure 126. Mesic Flatwoods with light damage (ocean side).

Figure 127. Mesic flatwoods with heavy damage.

Figure 128. Salt water damage to pines.

Because of the significant northerly wind from the storm, a heavy wrack of debris was observed in low spots on the bay side (northern section) of the park (observed at the base of dunes, in scrubby and wet flatwoods, and marsh). This debris is largely plant material but also contains trash (both small and large pieces) that washed up in the storm and settled in low lying areas when the water receded. In most cases, reintroducing fire as soon as feasible is the only further restoration pine forests on SASP need.

Beach Dune

Beach dunes are found on high ridges running parallel to the shoreline and are often found in a series of ridges and swales (coastal grassland) paralleling the beach and adjacent to scrub or flatwoods inland. Beach dunes vary in their vegetation cover from mostly open sand with herbaceous species such as seaoats (*Uniola paniculata*) on primary dunes to more shrubby species such as Florida rosemary (*Ceratiola ericoides*), woody goldenrod (*Chrysoma pauciflosculosa*), sand live oak (*Quercus geminata*) and sand pine (*Pinus clausa*) as dunes are more established and/or further from the coast (i.e., secondary and tertiary dunes).

The dune system at SASP has variable damage. The primary dune system has light to severe damage but is generally intact likely due to the northerly winds (Figures 129). The major damage to the dune system was to seaoats and other vegetation ,. However, because the root system was generally protected it is likely that these dunes will recover more rapidly than those observed in other parks.

Figure 129. Beach dune damage observed at SASP.

Maritime Hammock

On the Florida Panhandle coast, the forested portions of barrier islands are largely occupied by pine-dominated communities such as scrub, scrubby flatwoods, and mesic flatwoods. With maritime hammock found only in isolated pockets, often where shell is mixed with the sandy substrate (Johnson and Barbour 1990). West of Gulf County, sand live oak (*Quercus geminata*) replaces live oak in the canopy, occasionally mixed with sand pine (*Pinus clausa*) and slash pine (*P. elliottii*); cabbage palm is absent, having reached its western range limit (Johnson et al. 1992a). .

The storm caused variable damage from light to heavy. Heavy damage was generally isolated to small pockets and consisted of heavy canopy thinning with scattered downed trees (Figure 130). The oldest sand pines experienced heavy damage and high mortality. Damage to large sand live oaks consisted of heavy defoliation and limb loss with only occasional downed trees. Small trees of all species were generally undamaged.

Figure 130. Typical damage observed in maritime/xeric hammock.

Due to their coastal location with water barriers on at least one, if not two sides**,** fire was probably naturally rare and very patchy in maritime hammock, especially on the narrower barrier islands. Maritime hammocks are principally influenced by wind-borne salt spray, storm waves, and sand burial. Salt spray from both the ocean and bay sides of islands can enter and kill the upper buds, producing smooth, "pruned" canopies of evenly increasing height away from the coast. If storm waves destroy the protective dunes seaward of the hammock, sand can blow inland, burying the trees. Given the natural history of maritime these hammocks, storm damage is part of the longer disturbance cycles that shape them.

Task 3: Restoration Evaluation

Restoration options to consider include: prescribed burning, native planting, native seeding, mechanical removal of vegetation, and chemical control of exotic species (could be conducted in all areas with hazard tree removal). The purpose here is to outline what actions can be taken in the near term.

Recommendations Based on Historic and Current Conditions

Aerial photography from 1953 indicates historic conditions are likely similar to current conditions aside from areas cleared for park infrastructure and natural shifting of dunes (Figure 131). The most significant change to this landscape since 1953 is in the northwestern corner of Shell Island, the extreme NW portion of it being currently underwater. There are no further recommendations based on historic photos.

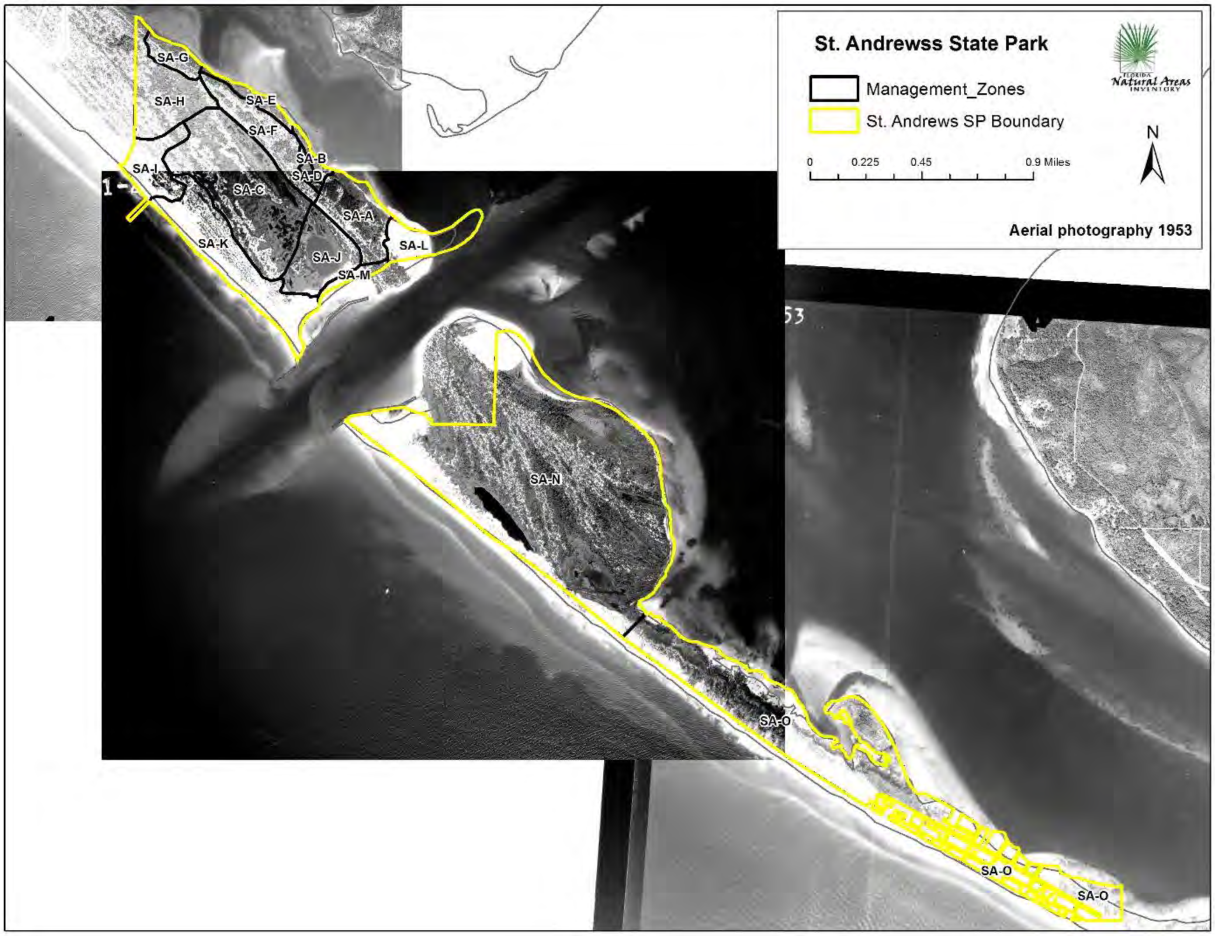

Figure 131. St Andrews State Park management units with 1953 aerial photography.

Task 5: Local Experts and Manager Workshop

On December 11, 2018, FNAI and DEP met with representatives of agencies and organizations at the Jones Center at Ichauway for a meeting to explore responses to the impacts of the storm on the region's forests. Primary goals were to share perspectives on the storm damage, discuss each organization's plans for assessing damage at finer scales on their properties, and their decision-making process in getting these forests back on a trajectory toward meeting management and conservation objectives.

Highlights of the meeting are summarized in Appendix I. In addition to land management representatives from properties across the affected area, several natural resource professionals with past hurricane recovery experience contributed to the presentations and discussions. A list of attendees is attached at the end of Appendix I.

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