



Appalachian/Piedmont/Coastal Fire Management Zone: Fire Effects Monitoring Annual Report, 2019





Past, Present, and Future of the Bullhead following 2016 GRSM wildfire.

Three years on, snags of the former Table Mountain Pine woodland are surrounded by a diverse and colorful community that features nearly all vascular plant life-forms: ferns, grasses, sedges, herbs, vines, shrubs, and numerous pine tree seedlings. Surveys of historical fires indicate that in several decades, this rapidly changing area will re-emerge as a dense pine forest.

On the Cover: *Limestone glade #24 at Chickamauga Battlefield in northern Georgia. NPS plans to use prescribed burning to reduce woody encroachment of these botanically diverse and globally rare natural communities.*

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January 2020

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Introduction

During 2019, the APC Zone Fire Effects Team conducted monitoring at seven National Park Service units, documenting the effects of 17 current and past prescribed burns, 5 mechanical fuel reduction projects, and 3 wildfires (**Table 1**). The total number of plot reads was 84, with a heavy focus on long-term postburn monitoring (61 reads). In many cases, this year's work allowed us to collect information on long-term fire effects following 3 burns, in plots that were established 15-20 years ago. These data are featured in various analyses throughout this report, and provide unique insights into the effects of a multiple-burn restoration fire regime. In particular, a report beginning on page 9 provides a unique analysis of multiple-burn effects on wildland fuels in the Appalachian Highlands. In addition to the focus on long-term data collection, it was an active and successful year for prescribed burning in our monitoring network, with fire-effects team members participating in 13 burns at three different parks (**Table 2**).

Collaboration was an important theme during 2019. One of the highlights of the year was the establishment of a brand new monitoring program at Chickamauga & Chattanooga National Military Park (CHCH). This effort involved a great collaboration between the APC Zone, CHCH staff, Region 2 Fire staff, the Cumberland-Piedmont Inventory and Monitoring program,



Allyson working with Forbes Boyle of the Southeast Coast I&M program on the prettiest plot in the country at Cape Hatteras.

and local scientists and managers. The need for prescribed burning to restore the globally rare limestone glades at CHCH has been known for many years, and all of the parties are working together to build a successful and sustainable prescribed fire program at the Park. Other highlights for the year included collaboration with the Southeast Coast Inventory and Monitoring program on vegetation and fuels monitoring with at Cape Hatteras National Seashore (CAHA), completion of an updated fuels map for Great Smoky Mts. (GRSM), completion of all APC Zone fuels treatment/wildfire mapping, and continued engagement with research partners. Such

collaborations are vital for achieving core NPS goals, and these combined efforts will *increase the amount* of information available to managers, *improve the quality and accuracy* of that information, and *enhance the transmission* of the information to decision-makers.

Efforts in the coming year will remain focused on short and long-term data collection to support fuels/vegetation management at multiple parks. We will continue to explore collaboration on monitoring with several networks of the NPS Inventory and Monitoring program, with the goal of enhancing delivery of usable information to park managers and fire practitioners. Another focus in the coming year(s) will be on enhancing data analysis capabilities and publication of findings. Data analysis will be directed toward understanding trends in burn severity, climate-fire interactions, fuel load changes, vegetation dynamics, and the implications of these trends for adaptive management.

**Table 1. Appalachian/Piedmont/Coastal Fire Effects Monitoring Program:
2018 Plot Workload and Total Plots Installed**

Park	Monitoring Unit	Plot Type	Pre-burn 2019	Immediate Post-burn 2019	Postburn (1-20 yrs) 2019	Annual Total (2019)	Total Plots
Big South Fork (BISO)	Little Bluestem	FMH Forest		2	3	5	4
	Shortleaf Pine	FMH Forest				0	2
	White Oak	FMH Forest		2	5	7	13
	LFEM	LFEM Forest				0	21
	CBI	CBI				0	9
	Fuels Transect	Fuels Transect				0	4
Blue Ridge Parkway (BLRI)	Chestnut Oak	FMH Forest				0	2
	LFEM	LFEM Forest				0	7
	Fuels Transects	Fuel Transect				0	6
Cape Hatteras (CAHA) *Assisted SECN I&M with monitoring in 2019	LFEM	LFEM Grassland				0	17
	Photo Points	Photo Point				0	33
	Photo Points (Non-Permanent)	Photo Point				0	10
Chickamauga & Chattanooga (CHCH)	Post Oak	LFEM Forest	3			3	3
	Bluestem Glade	LFEM Grassland	6			6	6
Congaree (CONG)	Loblolly Pine	FMH Forest			2	2	5
	Longleaf Pine	FMH Forest			1	1	5
	Harry Hampton Mastication	LFEM Forest			7	7	17
Cowpens (COWP)	Southern Red Oak	FMH Forest				0	2
Cumberland Gap (CUGA)	Scarlet Oak	FMH Forest			4	4	16
	Oak Forest	LFEM Forest				0	10
Great Smoky Mountains (GRSM)	Black Oak	FMH Forest		4	4	8	8
	Scarlet Oak	FMH Forest		1	6	7	15
	Yellow Pine	FMH Forest		2	7	9	40
	Oak/Pine	LFEM Forest		3	3	6	49
	Ski Mt.	Photopoints			10	10	10
	Oak/Pine	CBI			3	3	128
	Fuels Transect	Fuels Transect				0	7
Kings Mountain (KIMO)	Blackjack Oak	FMH Forest				0	8
	Chestnut Oak	FMH Forest			6	6	21
	Oak/Pine	LFEM Forest				0	20
	Fuels Transect	Fuels Transect				0	3
Moore's Creek (MOCR)	Photo Points	Photo Point				0	2
Total			9	14	61	84	503

Table 2. Summary of 2019 Prescribed Burns and Associated Monitoring

Park	Burn Unit	Plots?	Other Monitoring	Acres
Big South Fork NRRRA (BISO)	Bald Knob South	Yes (Full Plots)	Yes (Qualitative)	800
	Newtie King	Yes (Full Plots)	Yes (Qualitative)	130
Congaree National Park (CONG)	Red Bluff	Yes (Full Plots)	Yes (Qualitative)	450
Cumberland Gap NHP (CUGA)	Harlan Road	Yes (Full Plots)	Yes (FEMO, Qualitative)	236
Great Smoky Mountains (GRSM)	Lynn Hollow	Yes (Full Plots)	Yes (FEMO, Qualitative)	240
	Short Bunk	Yes (LFEM)	Yes (FEMO, Qualitative)	780
	Bald Top	No	Yes (FEMO)	284
	Maple Branch	No	Yes (FEMO)	324
	Cemetery Marsh (Feb)	No	Yes (FEMO)	223
	Rowans	No	Yes (FEMO)	22
	Elijah Oliver	No	Yes (FEMO)	9
	Old Field	No	Yes (FEMO)	85
	Cemetery Marsh (Nov)	No	Yes (FEMO)	210
	Tipton Oliver	No	Yes (FEMO)	135
	Cable House	No	Yes (FEMO)	84
Kings Mountain NMP (KIMO)	Brushy Mountain South	No	Yes (FEMO, Qualitative)	259
Moore's Creek NB (MOCR)	Savannah	No	No	24
	Northeast	No	No	30
Totals	18	6	16	4325

Table 3. Fire Ecology/Fire Effects Staffing 2019

Team Member	Starting Date	Ending Date	# of Pay Periods	READ (Yes or No)	Training and Development
Rob Klein (Fire Ecologist)	1/1/19	12/31/19	26	Yes	Guest lecture at WCU; GRSM Fuels Map; GRSM Mapsheets; SBR FLN; Bullhead field trip with Fire Managers from Mecklenburg Co., NC; Experience Your Smokies Reunion; Science Communication Training; AFE-Tucson
Wylie Paxton (Lead Monitor)	1/1/19	12/31/19	26	Yes	Assisted with Fire Refreshers at multiple parks; 130/190 @ GRSM; Lead Read for Hurricane Dorian; SBR FLN; Worked w/ SECN I&M at CAHA; I&M Conference; Science Communication Training
Matt Wood (Assistant Lead)	1/1/19	12/31/19	26	No	Assisted with Fire Refreshers at multiple parks; 130/190 @ GRSM; Led field trip for SIU-Carbondale Forestry; SBR FLN; Science Communication Training; RAWS management; RX burns at GRSM, CUGA, and KIMO
Allyson Arulanantham (STF Crewmember)	3/17/19	12/7/19	19	Yes	30-day detail with GRSM Module; Completed FEMO Task Book; READ for Hurricane Dorian; 130/190 @ GRSM; SBR FLN; solo presentation for Experience Your Smokies; Science Communication Training

Research Update

Current Research Permits for Fire-Related Research in CHCH

Resampling of woody encroachment in limestone glades of Chickamauga Battlefield

PI Tom Govus

Institution Private Consultant/Botanist

Current Research Permits for Fire-Related Research in GRSM

Overstory mortality effects on fuel accumulation from the Fall 2016 Chimney Tops 2 wildfire

PI Don Hagan

Institution Clemson University

Changes in Woody Fuel Loading and Ericaceous Shrub Cover from 2003 to 2019 in Great Smoky Mountains National Park

PI Adam Coates

Institution Virginia Tech

Developing a Fire History for the Mesic, Eastern Portion of Great Smoky Mountains National Park

PI Sally Horn and Mathew S. Boehm

Institution University of Tennessee

Evaluating the effects of 2016 wildfires on soil invertebrates in the southern Appalachians

PI Mac Callahan and Bruce Snyder

Institution US Forest Service and Georgia College

Are there non-additive effects of fire and urbanization on soil properties and plant community assembly and functional traits?

PI Jennifer Schweitzer and John Schwartz, as well as Karen Hughes and Charlie Driscoll

Institution University of Tennessee

Post-fire endophyte/mycorrhizal Study in Table Mountain Pine burn areas

PI Karen Hughes

Institution UT

Effects of the 2016 Chimney Tops 2 Wildfire on Salamander Abundance and Diversity

PI Benjamin Fitzpatrick

Institution University of Tennessee

Wildfire Effects on Salamander Populations in Great Smoky Mountains National Park

PI Bill Peterman, Dan Hocking, John Crawford, Joe Milanovich

Institution Lindenwood University, Frostburg State U., Ohio State U., Loyola of Chicago U.

Effects of Fire on Pathogens and Mycorrhizae Associated with Forest Trees and Woody Vegetation in Fire Damages Areas of Great Smoky Mountains Using Illumina Sequencing and Field Plot Collecting of Fleshy Fungi

PI Richard Baird

Institution Mississippi State University

Effects of a 20-Year Prescribed Fire Regime on Fuel Loading in the Southern Appalachian Highlands

Introduction

“There is virtually no knowledge of the fire effects that will be experienced in these biotic communities As a result, a wide range of effects will be considered acceptable.”

Page 1, Tabcat Creek Burn Plan (GRSM), 1997

Fuel reduction is a fundamental objective of prescribed burn programs throughout the National Park Service (NPS 2019, RM-18, Chapter 7). At many NPS sites in the southeastern U.S., fuels have reached high levels due to prevailing management strategies of fire suppression and fire exclusion over the past 80 years. These fuels now pose a risk to human communities and to the natural and cultural resources that parks are mandated to protect. High fuel loads in the Wildland-Urban-Interface can increase the risk of high-intensity wildfires that threaten safety and homes, and they can result in high-severity fires whose effects on natural resources are outside of historical norms. NPS units in the southern part of the Appalachian Highlands region have used prescribed burning and adaptive management to manage and reduce fuels for over 20 years.

Although several studies of wildland fuels have been published for the Appalachian Highlands region, there is little to no information about the effects of multiple burns on fuels (Waldrop et. al. 2010, Loucks et. al. 2008, Waldrop et.al. 2007, Harmon 1980). As a result, even as land managers throughout the region implement prescribed-fire regimes of frequent burning for fuels management and restoration of oak and pine forests, there is virtually no quantitative information with which to assess program efficacy, recalibrate expectations, or make operational adjustments. Such information is the foundation for decision-making within the NPS fuels management policy framework, and it is a practical necessity for effective adaptive management.

Long-term fire effects monitoring is used by NPS to provide science-based information for adaptive management of wildland fuels and other natural resources (NPS 2019, RM-18, Chapter 8). Specifically, monitoring data is to be used to determine whether program objectives are being met, to inform improvement of objectives and operations, and to determine if unforeseen negative consequences are occurring as a result of fire management activities. Long term monitoring efforts on NPS lands in the Appalachian Highlands began concurrently with prescribed-burn programs in 1997, and continuous monitoring of multiple-burn restoration fire regimes has occurred in four Parks since that time. Monitoring efforts feature a vegetation component and a fuels component, and this monitoring is expected to accompany prescribed-burn programs indefinitely into the future. This report provides an updated analysis of the effects of restoration fire regimes on dead-and-down fuels in oak and oak-pine systems of the southern Appalachian Highlands, with management implications. It is worth noting that this is a highly unique dataset that provides results from the effects of a 20-year, multiple-burn prescribed fire regime.

Methods

Study Site

The study was conducted in sites identified for burning within five National Park Service (NPS) units in the Appalachian Highlands region: **Great Smoky Mountains National Park (TN/NC)**, **Big South Fork National River and Recreation Area (KY/TN)**, **Cumberland Gap National Historical Park (KY/TN/VA)**, **Blue Ridge Parkway (NC/VA)**, and **Kings Mountain National Military Park (SC)**. Four of these parks (GRSM, BISO, CUGA, and BLRI) lie within the Central Hardwoods Ecoregion, while the fifth (KIMO) lies near the transition between the Central Hardwoods and the Southern Pine-Hardwood Ecoregions. In general, all burn sites had stand ages of at least 60-80 years, had not experienced burning for at least 40 years, and are believed to be representative of long-unburned oak and oak-pine forests of the Appalachian region. Average basal area within each park's burn sites ranged from 109 - 154 ft²/acre, and all sites share some combination of the following dominant tree species: *Quercus coccinea*, *Q. montana*, *Q. velutina*, *Q. alba*, *Pinus echinata*, *P. rigida*, *Acer rubrum*, *Nyssa sylvatica*, and *Oxydendrum arboreum*.

The NPS prescribed burning program in the Appalachian Highlands region began in 1997 at GRSM, and other parks followed in 2000 (KIMO), 2006 (BISO, CUGA), and 2013 (BLRI). A core programmatic goal for these NPS units is to improve ecological integrity by re-establishing an ecologically-appropriate fire regime for the management of vegetation and fuels. Goals for prescribed burning are consistent across parks and sites, and include: fuel reduction, reduction of understory woody stem density, regeneration of oak and yellow pine, and increased cover of native herbaceous species. The general strategy to achieve those goals is to implement a frequent (FRI 2-7) years, low-to-moderate intensity prescribed-fire regime. Prescribed burns have occurred in late winter, spring, and fall, with the vast majority of burns occurring during late winter to early spring. Plots with multiple burns were burned on a 3-7-(15) year fire return interval.

Field Sampling

107 permanent monitoring plots were established in 40 burn sites within five NPS units between the years 1997-2014. Plots were randomly located within long-unburned subxeric to xeric oak and oak-pine forests situated on ridgetops and south or west-facing slopes within the planned burn units. A subset of 41 plots representing 18 burn sites in four NPS units (GRSM, CUGA, BISO, and KIMO) has been burned three times, and this subset formed the core dataset for most of the analyses in this report.

Plots are 0.1 hectare in size (approx. ¼ acre), and each contains four randomly-oriented and permanently-marked fuel transects. Each fuel transect is 50ft in length, and data collection followed Brown (1974). Woody fuels were sampled by time-lag fuel moisture (TLFM) class, and each class was tallied along transects as shown in the following table.

TLFM Class (diameter)	Debris Classification	Sampling Distance
1hr (0-0.25 inch)	Fine Woody Debris (FWD)	6 feet
10hr (0.25-1.0 inch)	Fine Woody Debris (FWD)	6 feet
100hr (1-3 inch)	Fine Woody Debris (FWD)	12 feet
1000hr (>3 inch)	Coarse Woody Debris (CWD)	50 feet

Litter and duff depth was recorded to the nearest 0.1 inch at 10 points along each transect, for a total of 40 litter and duff measurements per plot. Seven of the plots at BLRI followed slightly different sampling protocols, with each plot containing two fuel transects, with 20 litter and duff measurements per plot.

Fuel measurements were typically collected within 1 year prior to the initial prescribed burn (00Pre), and then re-measured within 2 months of the completion of each prescribed burn (01Post, 02Post,...). Additional sampling was completed 2 years postburn after burn (01yr2, 02yr2, 03yr2) and again 5 years after each burn (01yr5, 02yr5, 03yr5).

Data Analysis

Pre-burn data from 107 plots (5 NPS sites) were used to characterize fuel load baselines in long-unburned oak and oak-pine forests of the Appalachian Highland region. Preburn and postburn data were summarized to characterize trends for total fuels, duff fuels, 1000hr fuels, and fine woody fuel dynamics for the subset of plots that have been burned three times (n=41, 4 NPS sites). Given the central role of litter as a carrier fuel, and the need to gain a better understanding of the timing of litter recovery cycles, all available data (variable sample sizes – see **Table 2**) were examined to create the most definitive picture of litter load dynamics. Due to sampling constraints, “yr5” postburn data for litter include several measurements from years 4-7. Hence, “yr5” values represent a grouped average for years 4-7 that is strongly weighted toward actual year 5 postburn measurements. 95% confidence intervals are provided.

Table 2. Variable sample sizes for litter fuel load.

Burn Status	Sample Size (n)
00Pre	105
01Post	96
01yr2	64
01yr5	42
02Post	69
02yr2	19
02yr5	33
03Post	44
03yr2	9
03yr5	7
04Post	10

Fuel loading was calculated using FFI (version 1.05.08) (<https://www.frames.gov/ffi/home>). Fuel loading (biomass) calculations follow Brown (1974). FFI default values for fuels constants were used for calculating fuel loading for FWD and CWD. Bulk density constants for litter and duff calculations follow Ottmar and Andreu (2007) values for southeastern species (“Hardwoods” or “Pine-Hardwoods”).

Descriptive statistics for fuel loading were generated by park, burn status, and fuel type (TLFM class, litter, and duff). As is typical for fire-effects data, results exhibited high levels of variability, extreme outliers, and skewness. Due to the high variability of the data, median values are reported for most variables, and the nonparametric Wilcoxon signed rank test was used to determine if differences in fuel loading between burn statuses were statistically different.

Results and Discussion

Pre-Burn Fuel Loading

Prior to burning, average values for total fuel loading varied between parks, from the lowest (13.6 tons/acre at CUGA) to the highest (24.9 t/ac at GRSM) (**Figure 1**). Differences between parks were almost entirely a function of the differences in duff fuel loading, which reached the highest values at GRSM. Additional analysis (data not shown) reveals that increased duff loading at GRSM largely resulted from the higher proportion of pine-dominated plots, which have higher average duff depth than oak-dominated plots. Prior to the onset of prescribed burning, duff fuels represented the heaviest fuel layer in all parks, ranging from 40-62% of total fuel loading.

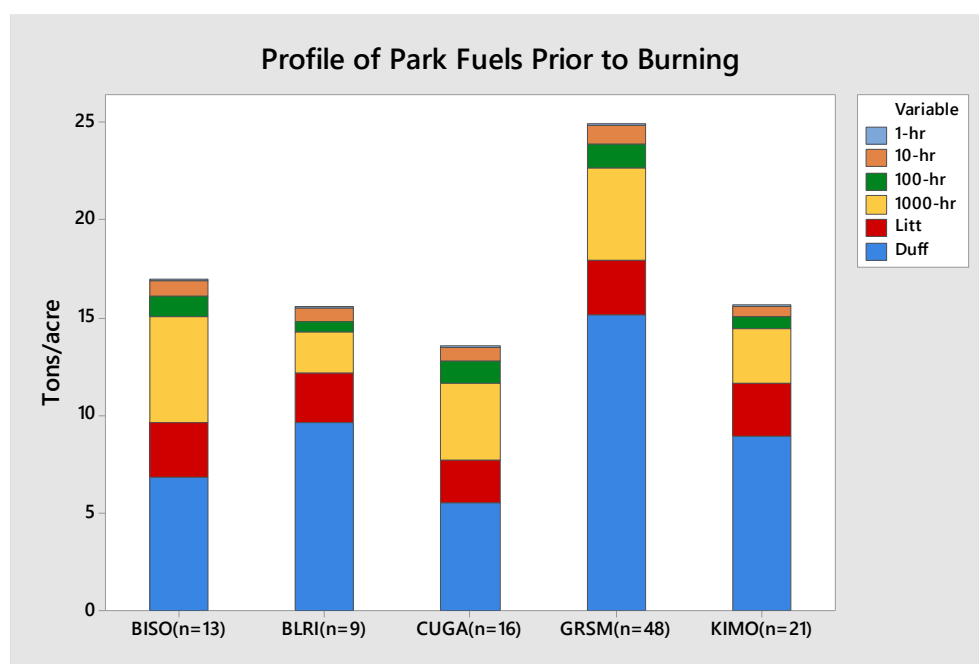


Figure 1. Average fuel loading by Time-lag Fuel Moisture class and by park prior to burning.

Coarse woody debris (1000hr) also varied between parks, with the highest (BISO) having 5.4 t/ac and the lowest (BLRI) having 2.2 t/ac (**Figure 1**). Conversely, the smaller TLFM classes (1hr, 10hr, 100hr), made up a relatively small proportion of total fuel loading (7-9%), and did not differ greatly between parks.

Leaf litter is the most readily available fuel, and it is the primary carrier of fire in Appalachian forest systems. Litter loading was moderate, and was consistent across parks in our sampling, ranging from 2.2 – 2.8 t/ac (**Figure 1**).

Fuel Load Changes Following Burning

Litter

The most obvious effect of prescribed burning in Appalachian forests is the consumption of leaf litter from the forest floor. In these systems, litter is the primary carrier of fire in nearly all cases, and moderate to high levels of consumption can be expected under average fire conditions. In the 15-22 year fire regimes represented by this study, litter fuel loading follows a distinctive pattern of repeated consumption and recovery (**Figure 2**). The mean pre-burn level of 2.7 t/ac was reduced by 81% following the first burns, recovered to 1.3 t/ac by the second growing season following the burns (equivalent to 1 leaf fall in most cases), and had recovered almost completely to 2.5 t/ac within 5 years.

This cycle was essentially repeated following the second and third burns, though levels of consumption and recovery varied somewhat. Average consumption during the second and third burns was 92% and 90%, respectively, while the mean recovery after the second burn was 2.1 t/ac after 5 years. Sample sizes following the third burn are all less than 11, so no inferences can be drawn from those values; however the general pattern of recovery and consumption was the same. Within the temporal scope of this analysis, it remains unclear whether effects of repeated burning on tree density will result in measurable reductions in litter build up over time. These data provide information on the cycle of consumption and recovery that managers can use to understand treatment lifespans, manage fuels, and plan future burns.

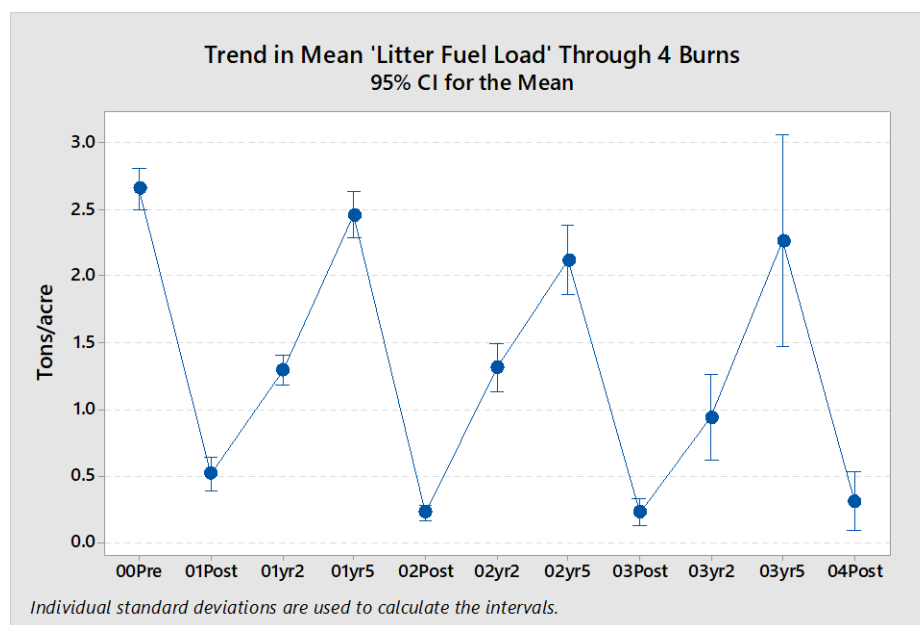


Figure 2. Trend in mean litter fuel load through 4 prescribed burns. Bars are 95% confidence intervals. Refer to Table 2 for sample sizes.

Total Fuel Load

Following a single burn, median total fuel load was reduced 30%, from 17.1 t/ac to 12.1 t/ac (**Figure 3**). Though total fuel load continued to drop after the 2nd and 3rd burns, these changes were not found to be statistically different than values following the first burn. One partial

explanation for this leveling out of total fuel reduction is that 27% of the plots actually experienced an *increase* in total fuel loading by the time of third burn. This result appears to be driven by the addition of woody fuels following the first and second entries of burning, which becomes an important consideration when setting goals and expectations for fuel reduction in the context of restoring fire regimes. We'll return to this dynamic later in this paper.

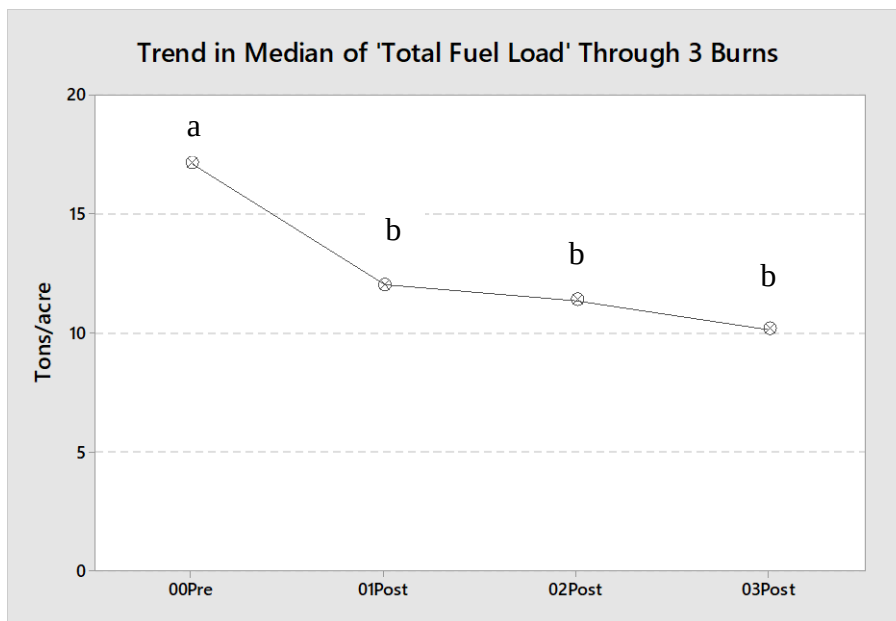


Figure 3. Trend in total fuel load. Values with the same letter(s) are not statistically different. Wilcoxon Test results with $P < 0.05$. ($n=41$)

Duff

The overall trend for duff fuel loading is a continuous, incremental reduction (**Figure 4**). This result is somewhat expected, because duff is the slowest fuel to accumulate, requiring many years without disturbance for litter and other surface fuels to break down into the smaller particles that characterize the duff layer. For this reason, it is unlikely that duff would increase under a regime of frequent fire, while additional burning slowly reduces duff thickness and loading. After a single burn, the median duff fuel load was reduced by 23%, from 7.9 t/ac to 6.1 t/ac. Significant reductions also occurred following the second burn (5.6 t/ac) and the third burn (4.1 t/ac) for an overall reduction of 48% following three burns. These reported changes in duff fuel loading are a function of the measured depth of the duff, and they correspond to a change from a median value of 1.6 inches to 0.8 inches in depth (data not shown).

The reduction of duff is a key fuels management objective, and an important ecological objective of prescribed burning. During extended droughts, duff fuels become available for burning and contribute to a much greater resistance-to-control for wildfires. This is especially true for pine and oak-pine forests in the Appalachian Highlands, where thick layers of duff (2-5 inches) have formed in the long-term absence of fire. Ecologically, thick layers of duff form a barrier to germination and establishment of pine and oak seedlings, thus preventing a process critical for the maintenance of these important natural communities. Thick duff layers also restrict the growth and spread of native herbaceous species, reducing species diversity and important food sources for wildlife.

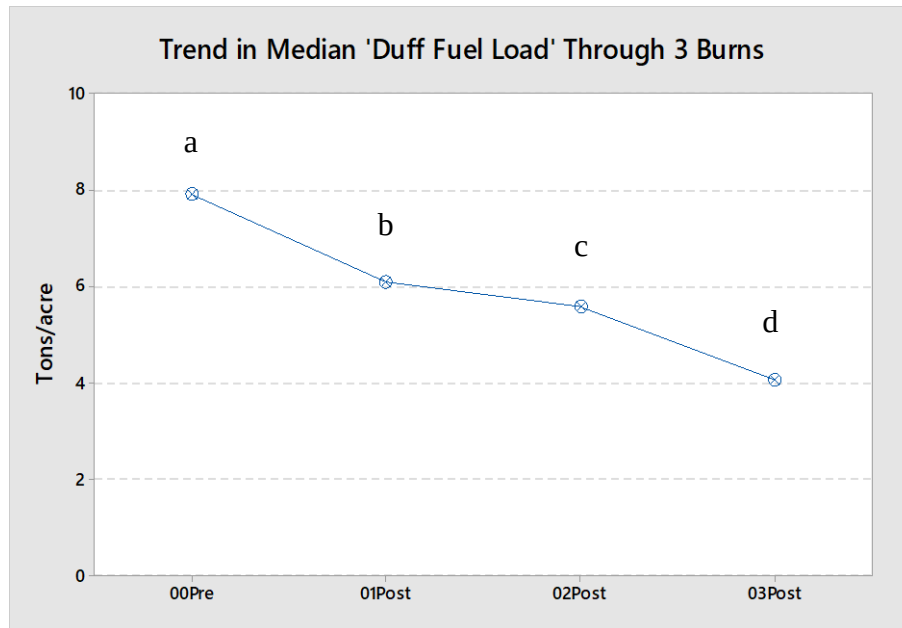


Figure 4. Trend in duff fuel load. Values with the same letter(s) are not statistically different. Wilcoxon Test results with $P < 0.05$. (n=41)

Most of these burns were conducted in late winter/spring, during a time when drought indices such as Keetch-Byram Drought Index (KBDI) are at relatively low values (e.g. KBDI < 100). This timing plays a key role in moderating the consumption of duff, which is a desirable outcome during the early burns of fire regime restoration. Within this dataset, there are examples of burns conducted during late summer/fall (KBDI > 300) that featured high levels of duff reduction (>60%), and these burns resulted in undesirable mortality of mature yellow pines due to duff consumption at the base of the trees (Jenkins et.al. 2011). A report (found in this annual report) on the 2016 Happy Valley Ridge wildfire at GRSM provides another good example of this type of extreme duff reduction.

Woody Fuels

The trends of fire effects on woody fuels were considerably different than those for litter and duff. Statistically, there was no change in median value of fine woody debris (FWD) following the first burn (**Figure 5**). However, FWD actually increased following the second burn, from a preburn median value of 1.5 t/ac to 2.2 t/ac (+ 46%). Though the median fuel loading declined slightly following the third burn, there was still an overall 40% increase following three burns. This result could be indicative of postburn increases from small fire-killed stems, but it also suggests that very little of these fuels are consumed during individual burn events. This matches with field observations during and directly after most prescribed burns, where many 10-100hr fuels are visibly not consumed. **Photo 1** illustrates how small diameter fuels can increase through the course of restoring fire regimes.

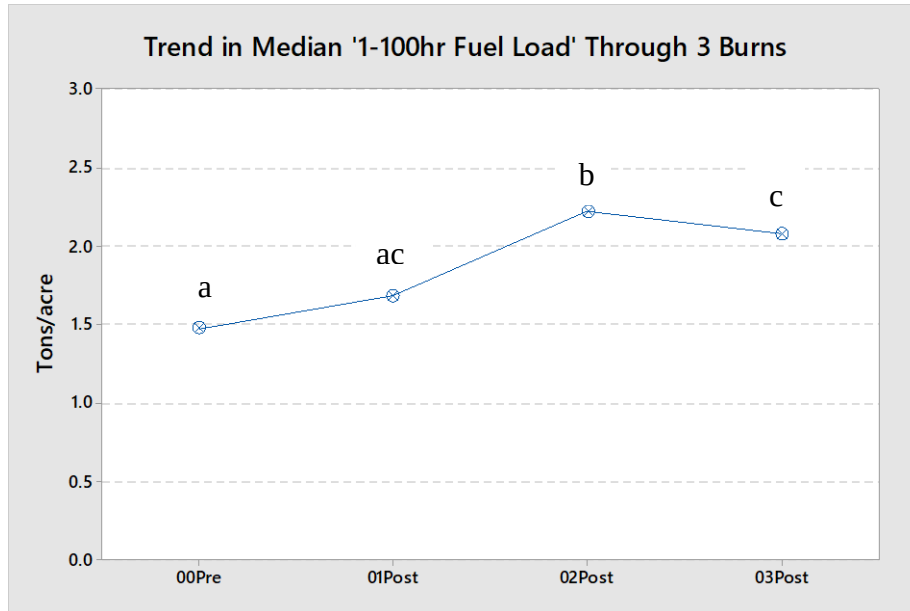


Figure 5. Trend in 1-100hr fuel load. Values with the same letter(s) are not statistically different. Wilcoxon Test results with $P < 0.05$. (n=41)



Photo 1. Third entry burn of the North-Central unit at KIMO. Good example of new inputs of 10 and 100hr fuels resulting from previous burns, and how they can persist during subsequent cool-season burning.

There was no statistical change in median values of 1000hr fuels through three burns (**Figure 6**). However, 23 of the 41 plots experienced an increase in 1000hr fuels following the third burn, as compared to preburn. Several of these increases were quite large, and this created immense variability in 1000hr fuel loading following the third burn (**Figure 7**).

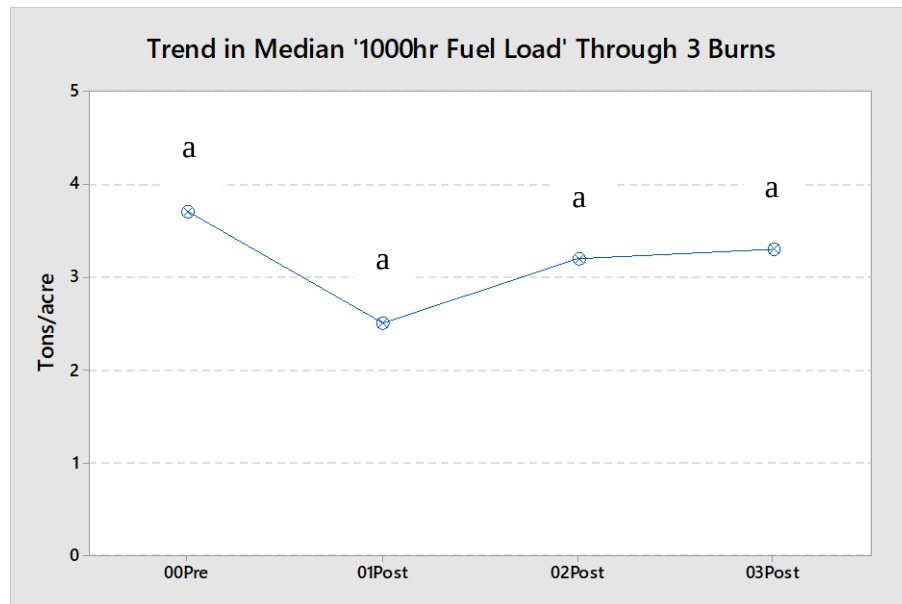


Figure 6. Trend in 1000hr fuel load. Values with the same letter(s) are not statistically different. Wilcoxon Test results with $P < 0.05$. (n=41)

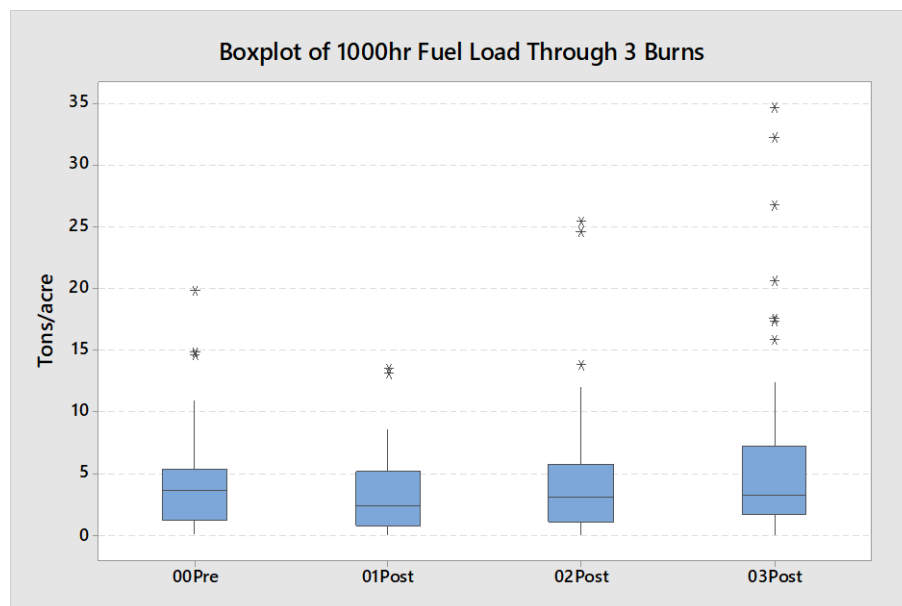


Figure 7. Boxplot of 1000hr fuel loading through 3 burns. Lines inside the blue box represent the median value for fuel load, boxes represent the middle 50% of datapoints, whiskers represent the upper and lower 25% of data, and asterisks represent outliers in the data. *The key thing this graph shows is that, while the median value after 3 burns (03Post) was lower than the pre-burn value, there are several plots (represented by the uneven box shape and number of outliers) that experienced an increase in 1000hr fuel loading.*

These fuel loading increases did not bend the curve enough to lend statistical significance to the overall trend, but they are important cautionary tales for prescribed burning practices. Though 1000hr fuels can increase in any given plot due to a variety of natural disturbances (wind, ice, forest pests, etc.), further analysis shows that the intensity of initial burning accounts for nearly 50% of the increase in fuel loading, presumably the result of fire-killed trees falling to the ground and becoming surface fuel. **Figure 8** shows the positive relationship between burning intensity (measured as average char height on trees) during the first prescribed burn and 1000hr fuel loading after 3 burns ($R^2=47.3\%$, $P<0.05$). You can see that when first-burn char height averages 1m (3.3ft) or more, there is a greater likelihood of elevated fuel levels by the third burn.

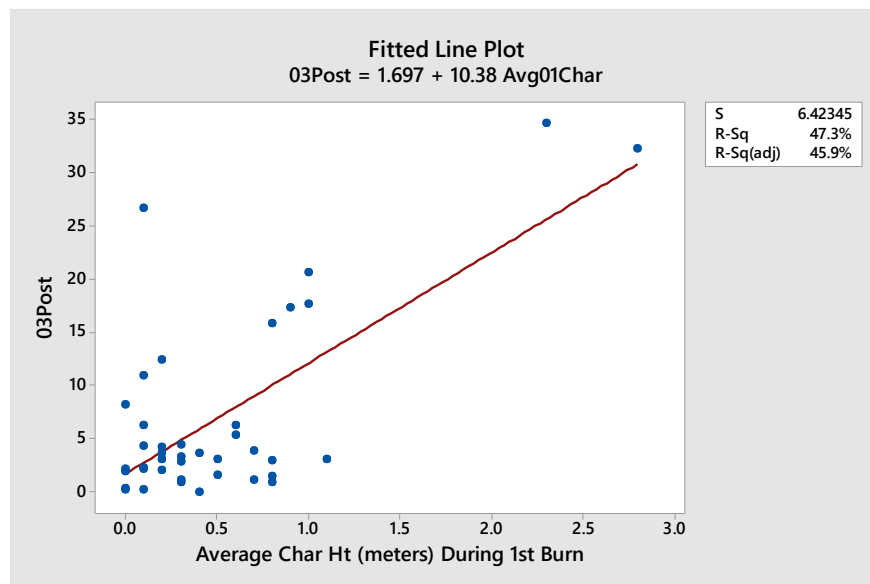


Figure 8. Relationship between average tree char height during the first burn and 1000hr fuel load after 3 burns.

Photo 2 provides an example of how this looks on the ground. This plot (QUCO01 at CUGA) experienced a moderate-intensity first entry burn in 2005 (avg. char height 2.3m (7.5ft)), and by the third burn (2014), new heavy fuels can be seen on the fuel transect. **Photo 3** provides another, slightly more extreme, view of post-burn fuel loading in plot QUCO01 (02POST, 2009).

The creation of woody fuel jackpots can pose a dilemma for achievement of fuel reduction and ecosystem restoration objectives. Large fuel increases, especially in areas along Wildland-Urban-Interfaces, can create additional fire control risks and complicate future burning. Such jackpots can also lead to additional mortality of desirable trees and fuel accumulation, by perpetuating expanding zones of tree mortality during subsequent burning.

It is important to note that some tree mortality and new fuel accumulation is a normal, and even necessary, process associated with prescribed-fire restoration. The caution is to avoid creating large, or self-perpetuating, areas of mature-tree mortality. Additional data are needed, but the existing data suggest that limiting average char heights on hardwoods should prevent unacceptable increases in woody fuels.



Photo 2. Long term monitoring plot QUCO01 at Cumberland Gap NHP. Right: Pre-burn photopoint. Left: Same photopoint, immediately after the third burn (03Post). Note the addition of heavy fuels resulting from initial prescribed burn.



Photo 3. Long term monitoring plot QUCO01, after the second burn. Note the large accumulation of heavy fuels resulting from fire-induced mortality.

Conclusions/Implications

- This study contributes to a much more nuanced understanding of how wildland fuels respond not just to individual prescribed burns, but to multi-burn fire regimes.
- Following burning, litter fuels are nearly completely removed; litter loading appears to recover to pre-burn values within 5 years.
- Prior to burning, duff is the heaviest fuel type in every park. However, duff loads appear to be consistently reduced over time with repeated burning, with virtually no new inputs in the short term. Research and anecdotal evidence from historical burns suggest that, without additional burning, duff loads can recover to pre-fire levels in 20-30 years.
- Pine forests have the highest levels of duff (and total) fuel loading. On average, duff fuels have been gradually reduced by restoration fire regimes, and this is a desirable result.
- Reductions in total fuel loading over time are limited by the addition of woody fuels resulting from fire-killed (and other) trees and shrubs.
- Plots with high levels of tree mortality can have substantial increases in long-lasting woody fuels.
- Fire effects do not account for all additions of heavy fuels. Trees are impacted by a variety of disturbances that can result in fuel load increases. Char heights greater than about 1m (3.3ft), which is closely correlated with tree mortality in eastern hardwood systems, accounts for about half of heavy fuel load increases.
- The strong implication from this study is to carefully manage overstory mortality to limit large inputs of heavy fuels. Existing data suggest that keeping average char heights on hardwoods below 1m (3.3ft) should prevent unacceptable increases in woody fuels.
- An additional implication is that existing objectives may need to be re-formulated to account for the reality of fuel creation during prescribed fire restoration.
- Additional research is needed to characterize, map, and accurately model live fuels (esp Mt. Laurel).

Big South Fork National River and Recreation Area (BISO): 2019 Fire Effects Monitoring Annual Report

Activity Summary

During 2019, the APC Zone fire effects team continued to provide fire ecology and fire effects monitoring services to BISO, although planning and operations services are now provided by the Mississippi River Fire Management Zone. Our team, including the fire ecologist, made two visits to BISO during 2019; the first to collect data on immediate post-burn effects of the Bald Knob (South) prescribed burn, and then later in the summer to more closely examine the fire effects on the vegetation in both the Newtie King and Bald Knob burn units.

The burns and monitoring work for Newtie King and Bald Knob South are described in the “Review of 2019 Projects” below. Long-term analysis of the trends in fuel loading through 15 years of prescribed burning at BISO are also included in the analysis of Appalachian Highland parks that begins on **page 9** on this Annual Report.

Review of 2019 Projects

Newtie King Prescribed Burn:

The Newtie King unit was burned for the fifth time on March 13, 2019. The Newtie King burn unit was identified in the 2005 Fire Management Plan, as a well-known and high quality grassland/sandstone glade at BISO. This unique site is comprised of an old homestead with a mix of old fields, native seepage wetlands, sandstone glades, native upland grassland, and successional forest, with the seepage wetlands, glades, and upland grassland being the focus of prescribed fire operations. With that said, the following quote taken from conservation professionals and scientists working with Southern Grasslands Initiative (<https://www.segrasslands.org/>) is fitting for the Newtie King unit.

Grassland loss is the single greatest conservation issue currently facing eastern North American biodiversity. Our precious Southern grasslands are nearly extinct and the species that depend on them are fading fast. Many of our Southern grasslands that managed to persist through the past 200 years have disappeared in the past quarter-century. What will the next 25 years bring? As a conservation community we are only now realizing how extensive our grasslands used to be. The losses have been truly staggering.

No FEMO report was filed for this year's burn, so there is limited information available about weather conditions or observed fire behavior. Burn severity mapping, long-term plot monitoring, and qualitative assessments were completed during the summer of 2019, and these data are provided below with annotations.



Figure 1. Newtie King burn severity map depicting 'very low' severity overall and 'very low' severity in both glade areas. These results can be broadly interpreted to mean that there was little change in the cover of woody species.

Table 1. Burn history and fire return interval (FRI) of the glades in Newtie King. The FRI for similar habitat in Darrow Ridge unit are provided for additional reference. The preferred FRI for this habitat is 1-2 years.

<i>Newtie King Glades</i> (2 plots, 5 burns)		<i>Darrow Ridge Glade</i> (1 plot, 3 burns)	
Burn Dates	Fire Return Interval	Burn Dates	Fire Return Interval
3/15/2005		4/24/2006	
4/11/2006	1 yr	3/24/2010	4 yrs
4/08/2008	2 yrs	4/21/2015	5 yrs
3/15/2013	5 yrs		
3/13/2019	6 yrs		



Figure 2. Long-term monitoring plot SCSC02. Top: August 2004, prior to initial prescribed burn. Bottom: The same point in July 2019. Note the large increase in small stems (mostly winged sumac) that survived the 2019 burn and/or resprouted vigorously, and the related reduction in grass cover. The solution for this is much more frequent burning (every 1-2 years).



Figure 3. Another view of SCSC02 in July 2019, just 4 months after the March burn. This area burned in a patchy and light manner. Note the survival of numerous small stems of thin-bark species (winged sumac) that are typically killed by surface burning. In future burns, these glade areas should be targeted with greater fire intensity.



Figure 4. The lower grassland complex (adjacent to the road) contains old fields, seepage wetlands, and sandstone glades. This area has received appropriate fire intensity, maintaining high forb and grass diversity with limited woody encroachment. More frequent burning would be beneficial here as well.



Plot SCSC03, August 2004. Preburn.



August 2005. Year 1 after 1st Burn



July 2006. Year 1 after 2nd Burn



July 2008. Year 1 after 3rd Burn.



July 2012. 5th year after 3rd Burn.



July 2019. 1st year after 5th Burn.

Plate 1. Long-term monitoring plot SCSC03. 2005-2019. Monitoring through 5 burns shows an initial decrease in woody stems, but with two longer gaps in treatment the woody growth has become reestablished. Refer to Table 1.



Figure 5. Wild quinine (*Parthenium integrifolium*)-a high quality native plant found on the upper glade of this unique site.

Key Takeaway Points

- Maintaining diverse grassland communities at this unique site is a high priority.
- Newtie King would benefit greatly from a more frequent fire return interval (1-2-(3) yrs), with higher intensity targeting the upper glade and woody encroachment.

Bald Knob South Prescribed Burn:

The second prescribed burn of Bald Knob South unit occurred on the same day as the Newtie King unit (March 13, 2019). The burns were completed separately by different crews. No FEMO report was filed for this burn. Burn severity mapping revealed that the overall burn severity was ‘very low’, which was confirmed by immediate post-burn monitoring completed in two long-term monitoring plots (**Figure 1**).

The south portion of Bald Knob tends to have solid mixed dry oak (white, scarlet, and black) with red maple and sassafras in mid-story. An extra section was added to the unit that had been unburned in the past. This section had no significant natural communities to speak of. In general the severity was very low, litter and light fuels consumed, small hardwood re-sprouts were top-killed and canopy remained intact. A photopoint from long term monitoring plot QUAL13 illustrates the general condition of these forests following the second burn (**Figure 2**).



Figure 1. Extended severity map, showing large parts of the landscape experienced a 'very low' severity burn. Small patches of 'low' to 'moderate' severity were mostly relegated to fields.



Figure 3. Plot QUAL 13. 'Very low' severity showing top-killed stems and somewhat open understory. This is a reasonable and acceptable result, especially early in the restoration process.

Bald Knob North Monitoring:

The original Bald Knob unit (now called Bald Knob North) lies directly adjacent to Bald Knob South. The north unit was burned last spring for the third time. This unit was originally burned in 2006, and has had fairly continuous monitoring of two plots through three burns. This area was highlighted by Julian Campbell in his 2001 report “Ecological Rationale for Fire for Fire at Big South Fork,” but the pine beetle outbreak of the late 1990’s and aggressive ignition from the first burn has created an ecological challenge to manage and restore (see **Figures 5 & 6** below). This site has been discussed in previous year’s annual reports; prior to the pine beetle outbreak, this site was known for outstanding examples of shortleaf pine woodland and sandstone glade vegetation, although little of the shortleaf pine remain. Some interesting isolated pockets of herbs remain on the landscape as seen in **Figure 4** (see also the 2011 Fire Effects Annual report).



Figure 4. *Parthenium integrifolium* and *Stenanthium gramineum* found inside the unit. These high-quality native herbs are vestiges of more open and sunny woodland conditions.



Figure 5. Long term monitoring plot QUAL03. Top: 2005 Preburn photo. Bottom: Same spot, 2019 after 3 burns. Following the creation of large gaps, and despite repeated burning, hardwood resprouts (in this case mostly red maple) grow back very rapidly. This result serves as a cautionary tale for creating large gaps during the early stages of oak and shortleaf pine regeneration. The site now needs to burn much more frequently (every 2-3 years?) to control these undesirable sprouts and allow opportunities for shortleaf pine and oak to regenerate.



Figure 6. Long term monitoring plot QUAL03. Top: The height pole (center, with pink flagging) demonstrates the height and density (!) of red maple sprouts less than a year and half after the third burn. The pink flagging sits at a 1.5m height (5 feet), and the sprouts range from 1-2m (3-7 feet). Bottom: Forest adjacent to QUAL03 with intact canopy. The response under this canopy is much more muted, with sprouts only attaining a height of 0.5-1m (2-3 feet). *Management of hardwood resprouting is a key consideration when implementing restoration fire regimes for oak and shortleaf pine.*

Key Takeaway Points

- 02 burn for the southern unit remained low intensity and kept over-story intact while top-killing smaller stems. A great solid low intensity burn.
- Slower and less aggressive ignition model has been successful in the Southern unit in not creating large canopy openings with large hardwood re-sprout thickets.
- Southern and Northern units may need to be treated differently as they are at different restoration stages.
- The northern unit should be burned on average of every 3-4 years to control the advanced response from hardwood resprouts. South unit could also burn every 3-4 years, but a 4-7 year rotation could also be effective. A long term commitment is needed for both.

Long Term Monitoring Results

Updates for this year were limited to herbaceous cover of glade plots. Most other items have been recently updated. Both the Newtie King and Bald Knob reports above contain outstanding examples of long-term monitoring results.

Table 1. Objectives and long-term monitoring results for BISO

Vegetation Type	Management Objective Restoration Phase- (After 4 burns)	Monitoring Results (80% confidence intervals)	Objective Achieved?	Year Last Analysis Completed
Dry Oak Forest (FQUAL1) <i>14 plots -</i> <i>11 have burned once</i> <i>7 have burned twice (3 Fuel Transects have also burned twice)</i> <i>5 have burned three times</i> <i>3 remain unburned</i>	>50% Reduction in total fuel loading	Total fuel load change After one burn (n=10): -52% ($\pm 3\%$) After 2 burns (n=8): -43% ($\pm 7\%$) After 3 burns (n=3): 46% ($\pm 27\%$)	Insufficient data. Trends need to be reexamined.	2018
	>70% Reduction in pole-sized tree density ($\leq 15\text{cm dbh}$)	Pole reduction After one burn (n=10): 62% ($\pm 11\%$) After 2 burns (n=4): 93% ($\pm 10\%$) After 3 burns (n=2): 69% ($\pm 27\%$)	Insufficient data, but the trend is very positive	2018
	20-40% Reduction in overstory tree density ($>15\text{cm dbh}$)	Overstory reduction After one burn (n=11): 5% ($\pm 3\%$) After 2 burns (n=5): 36% ($\pm 17\%$) After 3 burns (n=3): 28% ($\pm 40\%$)	Insufficient data, but the trend is very positive	2018
	>200 tall ($>1\text{m}$) Oak seedlings /ac	Oak Seedlings: Preburn (n=11): 199/acre (± 162) After 1 burn (n=11): 537/acre (± 276) After 2 burns (n=5): 1020 (± 545) After 3 burns (n=3): 1161 (± 334)	Insufficient data, but the trend is very positive. Objective may need to be revised.	2018
	>30% Cover by native herbs	After 1 burn: 14% (± 5) (n=11 plots)	Insufficient data.	2012
Little Bluestem Sandstone Glade (FSCSC1) <i>3 plots-</i> <i>2 have burned five times</i> <i>1 has burned three times</i>	>70% Reduction in pole-sized tree density	Pole reduction: After 1 burn (n=3) = 14% ($\pm 16\%$) After 2 burns (n=3) = 29% ($\pm 23\%$) After 3 burns (n=3) = 34% ($\pm 23\%$) After 4 burns (n=2) = 35% ($\pm 20\%$)	Insufficient data, but the trend is very positive. Objective may need to be revised.	2018
	>100% Cover by native herbs	Preburn cover: 98% (± 26) After 1 burn (n= 3): 123% (± 28) After 2 burns (n= 3): 133% (± 30) After 3 burns (n= 3): 102% (± 32) After 4 burns (n= 2): 138% (± 71)	Insufficient data.	2019

Note: Underscored sample size indicates that minimum plot numbers exist for $\alpha = 0.20$

Blue Ridge Parkway (BLRI):

2019 Fire Effects Monitoring Annual Report

Activity Summary

The APC Zone Fire Effects team supported the Parkway prescribed burn program in 2019 by participating in, and reporting on, the Grandfather Corridor prescribed burns. These burns were conducted to benefit *Liatris helleri*, a Federally Threatened species. Allyson Arulanantham attended this 1-day series of burns, providing monitoring and reporting of weather and fire behavior conditions. This information is summarized below, and through a collaborative effort with Parkway staff, this year's annual report includes results from post-burn monitoring of *Liatris helleri* populations.

Fire Effects Summary for Grandfather Corridor Rx 03 Prescribed Burn:

The Grandfather Corridor Rx burn was conducted on March 26, 2019. This burn was a significant landmark for the Appalachian Piedmont Coastal Fire Management Zone and Blue Ridge Parkway. The 3 sites in this corridor are highly ecologically significant because they are home to over half of populations of the Federally Threatened Heller's Blazing Star (*Liatris helleri*). This endemic herbaceous plant of the Asteraceae family is known from only a few populations and several counties in the Blue Ridge Mountains. The plant is globally imperiled, along with the high elevation, rock and cliff community that the plant occupies. Studies show that these Grandfather Corridor populations are unique; they are now known to be genetically pure *Liatris helleri*, while other populations of *L. helleri* have some crossing with *Liatris turgida*.

Human trampling and lack of fire have long been a concern for managers, because both of these degrade the habitat where the plant grows. The thinly vegetated margins surrounding the rock slabs where the plants grow is experiencing woody encroachment of shrubs such as sand myrtle (*Leiophyllum*) and blueberry (*Vaccinium*). Accumulation of litter, and shading by surrounding shrubs both act to inhibit the germination of *Liatris* seeds.

Resource managers have previously used similar micro-site specific fire application to burn away woody encroachment and maintain open, bare ground around monitored populations in 2005 and 2007. Past monitoring has shown this to be an effective technique.

Objectives for the burn:

1. Decrease shrub cover, primarily *Vaccinium* and *Leiophyllum*, by 70%
2. Decrease litter depth by at least 70% across the site
3. Remove litter and duff over at least 50% of the area to allow *Liatris* seeds to contact mineral soil

Burn Day Weather:

Burn day weather was mostly overcast with temps in the mid 30's-40's and Rh in the 90% range. Winds were calm and fog turned to drizzling rain in the afternoon. Such a cool and moist weather prescription was planned to reduce spread of fire outside the target area. These conditions allowed very minimal holding operations, and holding efforts were bolstered by rocky breaks on vegetation and fuel cover.

All *Liatris* plants were dormant during the time of the burn and increased humidity and cool temperatures were appropriate for reducing risk of harming the perennial root structures (corm) of the plant.

Propane torch
used for ignition
of vegetation.



Fire Behavior and Fire Effects:

Firing began in the area of the largest population. The propane torch pictured above was used in a manner to specifically target areas of sand myrtle and blueberry. Leaf blowers and wind gusts were utilized to get saturated litter to burn. The sand myrtle burned predictably well with flame lengths 4in-2ft in exposed areas. In most areas the litter was not consumed completely, and at the time of the burn it was thought that the burn conditions should have been a little drier in order to facilitate greater consumption.



Blueberry, sand myrtle
and laurel being top-
killed, reducing the
cover of plants that act
to shade out *Liatris*.

Post-burn evidence
of consumption of
sand myrtle and litter



No quantitative monitoring of fuel reduction objectives was completed, but the consensus following the burn was that the site was not adequately burned to meet the objectives. Specifically, BLRI managers felt that greater litter removal and shrub reduction would be needed to effectively open areas for new *Liatris* plants to germinate. Initially, the thought was to try to re-burn the sites later in the spring, but this ultimately did not happen. However, subsequent monitoring still revealed some encouraging results.



July 2019 monitoring of *Liatris* stem counts by BLRI staff.

BLRI staff monitored the *Liatris* populations during the 2019 growing season monitoring, and found an increase of several hundred flowering stems (**Figure 1**). These results appear to continue a trend that began prior to the burns in 2018, that may have been related to record rainfall totals. Thus, without closer research, managers can't say how much of the population increase was due to the effects of burning; however, photos (above) of the site just after burning clearly indicate that burning did provide for some increase in available habitat. Another round of monitoring is planned for July 2020, and the hope is to continue to use fire to manage the site. **A takeaway** from the monitoring of this burn is that it would likely be more beneficial to burn this site under slightly warmer and drier conditions (refer to *Burn Day Weather* section above).

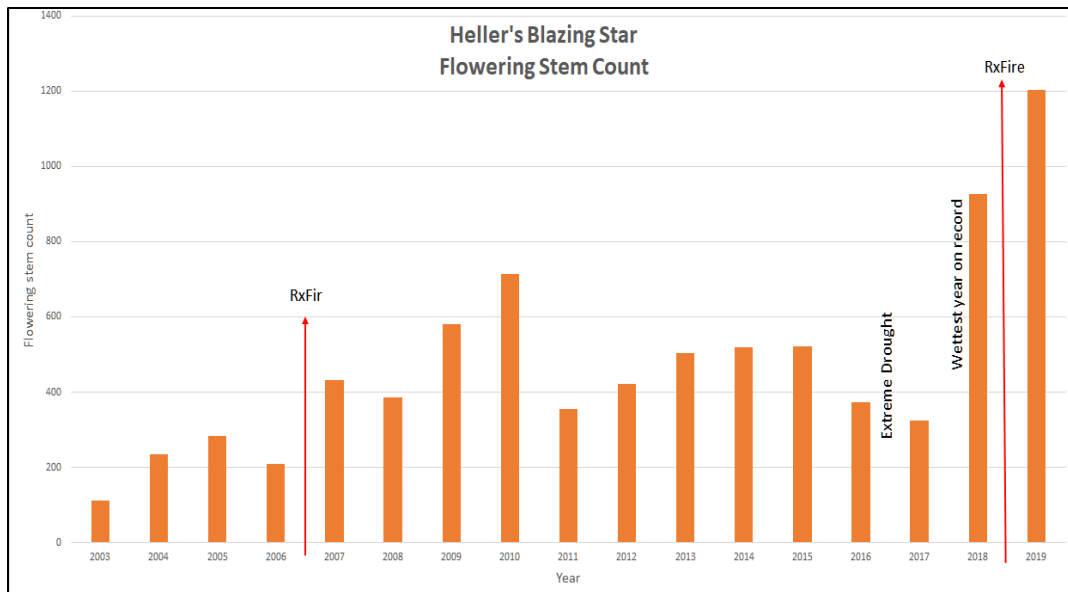


Figure 1. Stem counts for *Liatis helleri* 2003-2019. Significant weather and disturbance events are noted.

Cape Hatteras National Seashore (Outer Banks Group): 2019 Fire Effects Monitoring Annual Report

Activity Summary

During 2019, members of the APC Zone Fire Effects Team provided training and monitoring support during two separate visits. In addition, Wylie Paxton and Allyson Arulanantham worked as Resource Advisors (READs) during the Outer Banks *All-Hazard Incident Management Team* response to Hurricane Dorian. Familiarity with local resources and staff proved helpful in ensuring adequate resource protection during the initial post-Hurricane recovery.

Early in the year, the Wylie and Matt Wood assisted in providing annual firefighter refreshers for staff of the Outer Banks Group. Though not a monitoring activity *per se*, this kind of support serves to enhance communication of fire management and fire-ecology information to Outer Banks staff.

In July, Wylie and Allyson participated in an exciting monitoring collaboration with the **Southeast Coast Network Inventory and Monitoring program (SECN)**. The teams worked together to collect vegetation and fuels data at numerous locations throughout the National Seashore, which facilitated great dialogue about how the work of the two monitoring programs might better complement one another. The hope is to build on this collaboration in the coming year, both at Cape Hatteras and other NPS units. One future idea for Cape Hatteras is to combine Fire Effects and I&M datasets to enhance the existing wildland fire fuels map for the Seashore. Such a product would be incredibly useful not only for assessing risk, but for informing our understanding of Outer Banks fire ecology.

Review of 2018-2019 Projects

Monitoring of Mechanical Fuel Breaks:

Monitoring of mechanical fuel treatments was accomplished by photo-documentation and collection of brief notes regarding vegetation, width of treatment, and observations regarding effectiveness lifespan. Most fundamentally, a map was created documenting where the project work took place, often in coordination with CAHA GIS Specialist. In any event, completion of these maps and submission for inclusion in the NPS National Fire Database are the most critical monitoring tasks.

FY18 Mechanical Treatments Buxton Housing:

The Loggerhead Lane housing area was mechanically treated with chainsaws. The fuel break was approximately 15 feet wide on the Jeanette's Sedge Marsh side of the housing. The total acres treated were ~0.3. The housing occupies a remnant dune area, and successional vegetation and freshwater marsh shrub species are dominant vegetation. The eastern extent of the housing area borders Sand Live Oak and Live Oak hammock vegetation. The fuel break was mapped and five photo points were taken to document the work. A sample photo point is included below. The photo was taken before the cut fuels were removed.



Figure 1. The Buxton Housing fuel break was newly treated after a long hiatus and has opened up a distinct fuel break around park housing. Given the vegetation type and climate, annual or biennial maintenance may be necessary to keep it open.

South Nags Head-Mechanical Treatments- Monitoring recap from 2018:



Figure 2. Map of fuel break and monitoring plots

South Nags Head treatment was mostly completed by USFWS agreement in, 2015, 2017, 2018, and 2019. This treatment typically occurs in the spring of each year. It is unclear if 2012 was done by NPS Fire or Power Company.

In the fall of 2018, 6 Photo-points were installed and basic data was collected such as width of cut, length, vegetation composition and average vegetation height. Of the 6 points, 4 of them were the approximate location of Photo Points established in 2012, and attempts were made to recreate those points although perfect replication was not possible. A brief check on the fuel break in the fall of 2019 yielded the same results as 2018 treatment.

The South Nags Head Fuel Break is bordered by a row of dense development on the East side with a tall shrub and grass component on both sides of the power line/fuel break. The average width of the fuel break is 57 ft. and it is approximately 5 miles long (**Figure 2**). The total area treated is approximately 26 -30 acres. The vegetation height 6 months after the cut averaged around 1-3 feet tall, and the vegetation was primarily grass.

The area is a mosaic of marsh and scrub (**Figure 3**). The salt marsh vegetation contains *Phragmites australis* along with native plants like black needle rush (*Juncus roemerianus*), Marsh fern (*Thelypteris palustris* var. *pubescens*) and *Spartina* spp. As the landscape undulates to slightly higher elevation, shrubs such as Wax myrtle (*Morella cerifera*) yaupon (*Ilex vomitoria*) and the invasive plant vaseygrass (*Paspalum urvillei*) become a more dominant component.

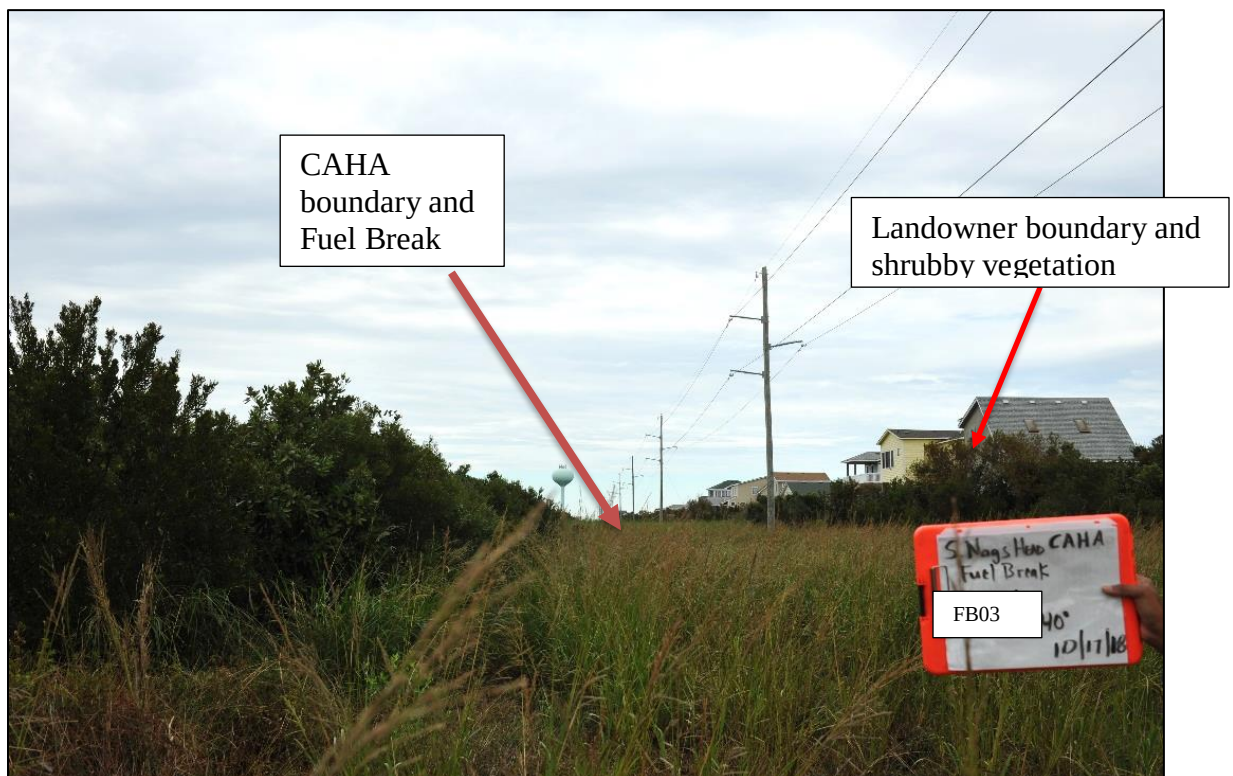


Figure 3. Photo point FB03. South Nags Head Fuel Break separates dense scrub vegetation from hundreds of home in South Nags Head. Many homes have scrub vegetation adjacent to structures.



Figure 4. Photopoint FB04 (aka 32) illustrates fuel height within the break and the edge of the cut. The cut provides defensible space with much lighter fuels than the adjacent scrub habitat. However, by autumn, some parts of the fuel break (e.g. the southern-most end) have 10-foot tall stands of Phragmites.

Fort Raleigh Fuel Break- recap of 2018 work:

The FORA area is more upland and associated with maritime forest and loblolly pine. The subdivision Heritage Point is located on the site of former Confederate war encampment and borders the park boundary with fairly dense maritime forest vegetation on either side. In 2018, a fuel break was completed on the North and West side of the community. Further work was completed in 2019 and then in the late summer of 2019, Hurricane Dorian hit the Outer Banks. The early fuel break work was compromised to an extent, but may have been mitigated by the Eastern Incident Management team crews.

Figure 5 indicates the location of the fuel break and monitoring locations (non-permanent). Photos (**Figures 6 & 7**) depict the work completed in 2018. Figures 8 & 9 illustrate some of the workload created by Hurricane Dorian.

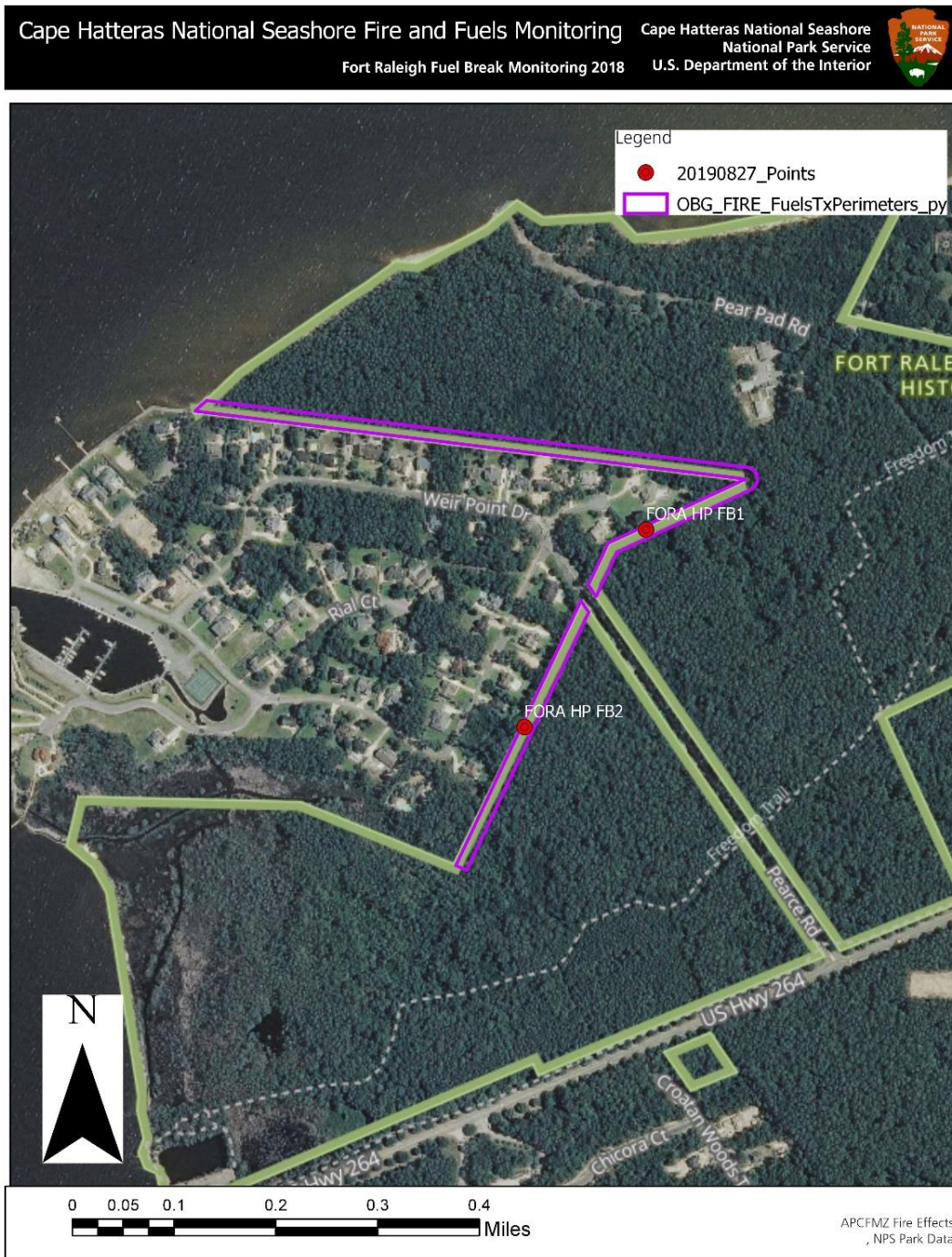


Figure 5. Fort Raleigh Fuel Break completed in 2018 and adjacent Heritage Point subdivision.

The total area of this treatment was approximately 5 acres. The length and width of the FORA fuel break is $\frac{1}{2}$ mile x 30 feet. The vegetation is generally associated with more coastal upland species. Loblolly pines (*Pinus taeda*) dominate the overstory as well as Live Oak (*Quercus virginiana*). Sweetbay (*Magnolia virginiana*) and yaupon (*Ilex vomitoria*) tend to occupy the midstory and shrub layers. The ground fuels are compact needle/leaf litter.



Figure 6. FORA Photopoint01 illustrates the maritime forest fuels and width of the fuel break (30ft).

The Heritage Point FB Photo 2 and 3 (**Figure 7**) are located on the south side of Pearce Blvd and had a higher pine component. The fuel bed had deeper litter layer here than at photopoint 01. The far SW corner of this fuel break ended in swamp type forest with standing water.



Figure 7. FORA Photopoint02 illustrates a greater pine component on the west side of Pearce drive. It is unclear what the effective lifespan of this treatment will be, but this monitoring helps to establish a baseline.

In August of 2019, the Heritage Point and Headquarters area saw significant tree damage from Hurricane Dorian. The fuel break was compromised in multiple places, and the following photos show some of the impact (Figures 8 & 9).



Figure 8. North/East end of Heritage fuel break illustrates light Hurricane damage to completed line.



Figure 9. Hurricane Dorian created a disruption in the cleared fuel break by up-rooting and breaking trees.

Chickamauga/Chattanooga National Military Park (CHCH): 2019 Fire Effects Monitoring Annual Report

Activity Summary

2019 was an exciting year for fire effects monitoring at CHCH. Aside from assisting with the annual firefighter refresher in February, the fire ecologist and fire effects crew made two visits to meet with local experts, and conduct pre-burn monitoring of the Viniard-Alexander prescribed burn site in the Chickamauga Battlefield unit (**Figure 1**). In February, the team met on-site with Tom Govus, a professional Botanist who has studied the vegetation and glades of CHCH for nearly 15 years. Mr. Govus is conducting a long-term repeated study of the Park's limestone glades, and he was able to orient us to the site and share some of the findings of his long-term study. His continued work will be a great complement to our own monitoring efforts.

In August, the ecologist and crew returned for an incredibly productive week of monitoring. Assisted by Bill Moore, Ecologist from the **Cumberland-Piedmont Inventory and Monitoring Network (CUPN)** and Missy Forder, Region 2 Deputy Fire Management Officer, the team installed a total of 9 *permanent plots* in the glades and oak/pine woodlands within the burn site. 6 plots were installed and sampled across the three major glades within the site, and 3 plots were installed in representative oak/pine woodlands. These pre-burn plots will serve as a baseline for determining if resource objectives are being achieved through the prescribed burning program. Resource goals and objectives for the glades and woodlands are included below for reference.

Assuming the Viniard-Alexander burn is completed during late winter/spring of 2020, each plot will be re-sampled immediately after the burn for fuel reduction and burn severity. Effects on vegetation will be resampled during the summer of 2020. Collaboration with CUPN and Tom Govus will offer additional datasets and insights to aid in evaluating the effectiveness of the burn program.



APC Zone Lead Monitor Wylie Paxton and Region 2 DRFMO Missy Forder establish a pre-burn photopoint in Glade Plot 1. Each Glade plot consists of a permanently marked 5m-radius circle, and includes 4 photos and cover values for all plant species.

Goals and Short-Term Objectives for Glades and Oak/Pine Woodlands at CHCH:

A. Glades

Long-term goal: Maintain or expand current areal extent and species composition of herb-dominated glades by reducing woody stem density and limiting future woody encroachment.

- a. Burn at least 90% of herb-dominated glade area
- b. Consume at least 80% of fine fuels over the burned area
- c. Top-kill >40% of small woody stems (less than 2.5" dbh) within the glade perimeter

B. Oak/Pine Woodlands

Long-term goal: Restore an oak/shortleaf pine/(loblolly pine?) woodland characterized by an open canopy and midstory, adequate oak and shortleaf pine regeneration, and >30% cover of native herbaceous species.

- a. Burn at least 70% of area currently dominated by oak, loblolly pine, or shortleaf pine
- b. Consume at least 80% of fine fuels over the burned area
- c. Top-kill >30% of small woody stems (less than 4" dbh) within oak and oak-pine forest

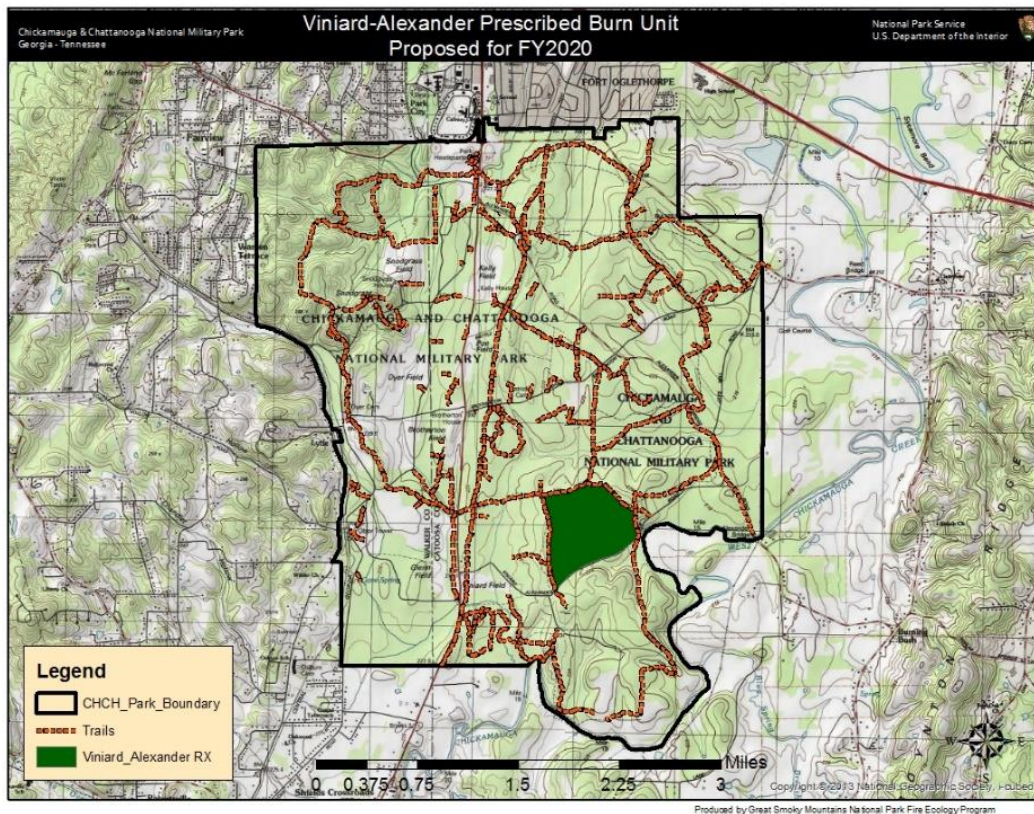


Figure 1. Location of proposed Viniard-Alexander prescribed burn unit.

Congaree National Park (CONG): 2019 Fire Effects Monitoring Annual Report

Activity Summary

The APC fire-effects monitoring crew made one visit to Congaree during 2019. This was our annual monitoring trip during June, and the work focused on post-burn monitoring of the Red Bluff/Dawson's Cabin prescribed burn, and completing surveys for invasive plants in the Harry Hampton mastication area. This work is briefly discussed below in the "*Review of 2019 Projects*" section of this report. Additional long-term monitoring was completed in the permanent plots located in the RCW prescribed burn unit.

Review of 2019 Projects

Red Bluff/Dawson's Cabin Prescribed Burn:

Red Bluff Road and Dawson's Cabin units were prescribed burned for the sixth time on April 25, 2019. The unit boundaries varied slightly from the past, and included the private section on the Northwest corner. The logging road that was formerly used as the north boundary no longer could be used as a holding line, so a mastication line was put in right on the NPS boundary that runs parallel with the road. The use of this line as the north unit boundary will continue into the foreseeable future due to legal concerns with the landowners and lack of MOU's.

The objectives of the burn should be to: 1) reduce litter fuels by >80% across >80% of the unit, and 2) top-kill >80% of sweet-gum sprouts. No fire effects personnel attended this burn, and no FEMO report was filed for the burn. With that said, burn-severity mapping and a growing season visit to the unit yielded critical information on the effects of repeated burning at the Red Bluff/ Dawson's cabin unit. Both remotely-sensed burn-severity mapping and the monitoring survey detected overall light severity with only a modest amount of canopy opening. Understory effects were more pronounced along the control line, with trees less than 4" in diameter beginning to be thinned out, and increased grass and forb component expanding in an edge zone that is about 100 feet from the North line. As the unit expands to the south, tree sapling density and over-story canopy shade increases. Once the unit approaches the bluff line, there is a distinct vegetation change, and fire typically has gone out there.

Much of the low and moderate (aqua blue and yellow) severity detected in the northwest corner of the unit (**Figure 1**) is due to the private section having been clear cut. The sliver of NPS land that shows moderate severity has only burned prior to this event in the 2018 wildfire and likely has secondary mortality from this year's burn. Smaller pole-sized tree islands remain throughout the unit (**Figures 2 -5 below**).

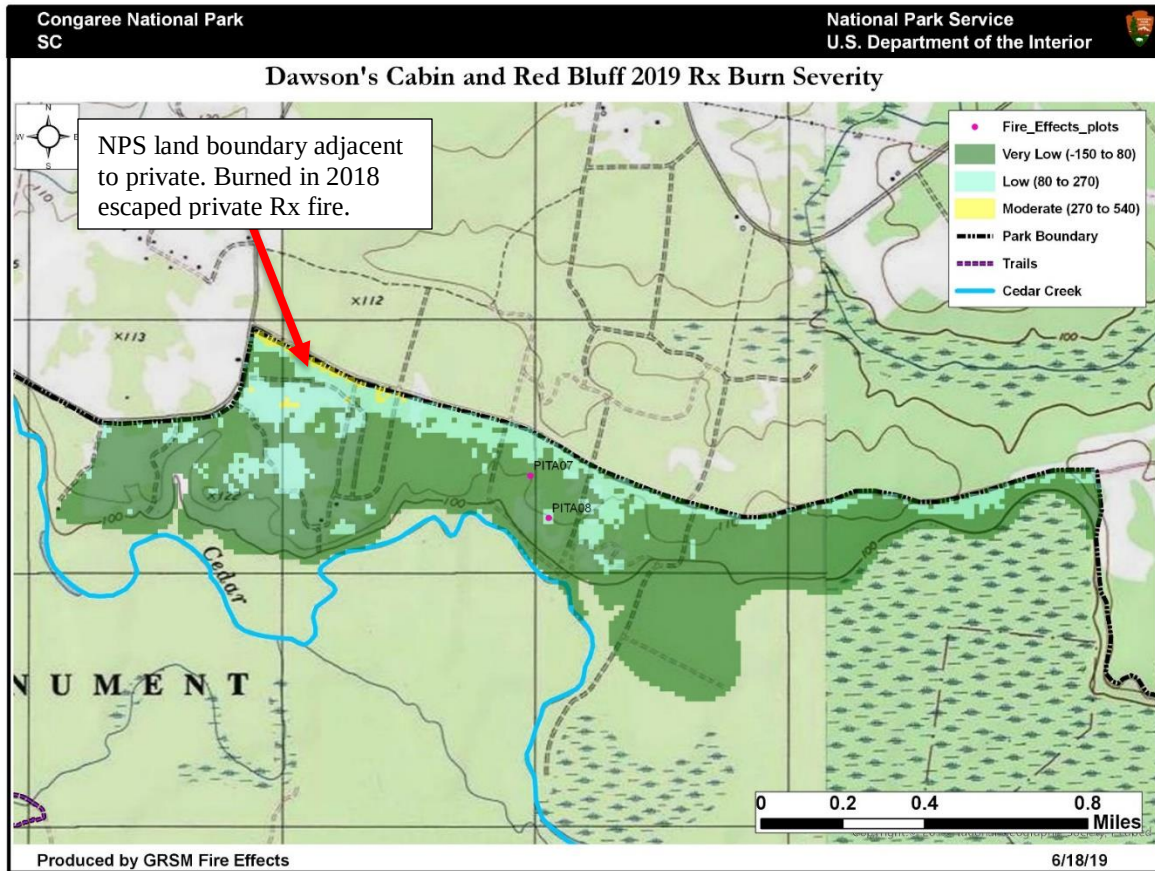


Figure 3. Initial Burn Severity following Spring 06 Burn

Key Takeaways

- Low severity (aqua blue) along road edge indicates decreased density of pole-sized trees, greater light availability, and increased grass response.
- The repeated burning has been effective in creating more open conditions, but only within first 100 feet of road. Beyond that first 100 feet, fire effects have been patchy, and patches of sweetgum sprouts have escaped the past two prescribed burns. **See photo series below.**
- Mechanical treatment may be necessary to achieve the desired woodland structure, though any clearing should be monitored for invasives. Private land directly adjacent to the unit has a large infestation of Sericea (*Lespedeza cuneata*).

FMH Plot PITA 08 – Red Bluff Road Rx Burn Unit
*Photo series show gradual opening of canopy and
regrowth of understory sweetgum from 2005-2019.*



Figure 2. Plot PITA 8 - Preburn, May 2005.



Figure 3. Plot PITA 8 - Following two burns. May 2010.



Figure 4. Plot PITA 8. Following the 4th burn. July 2014.
Note the increase in light infiltration and the excellent top-kill of sweet-gum resprouts.



Figure 4. Plot PITA 8. Following the 6th burn. June 2019.
While the canopy remains open, the 2019 prescribed burn was patchy (as was the 2017 burn), leaving islands of surviving sweet-gum sprouts, which can quickly grow large enough to escape fire.

Harry Hampton Mechanical Treatment Monitoring 2019:

In 2019, no further mechanical treatment occurred in the core area of the unit, although some hand thinning occurred around buildings. Work during this trip centered on two things: 1) photography of mechanical treatment plots, and 2) survey for invasive plants. Photo-monitoring of mechanical treatment plots document the success of herbicide treatments as a follow up to control sweet-gum sprouts (**Figures 1 and 2**).



Figure 1. Plot MT-12, June 2017. First growing season after mastication treatment.



Figure 2. Plot MT-12, June 2019. Subsequent burning and herbicide treatments have helped maintain the open understory created by the mastication treatment.

Repeated observations of *Sericea lespedeza* following the 2014 Rx burn created an impetus to conduct surveys in the areas north and south of the campground. The crew of 3 created track logs and waypoints where the following exotic species were found, whether they were individuals or clumps: *Sericea lespedeza* (*Lespedeza cuneata*), Mimosa (*Albizia julibrissin*), and shrubby lespedeza (*Lespedeza bicolor*) (**Figure 3**). Each point will either mark a clump or individual. Most of the points are *Sericea lespedeza*. **Table 1** summarizes the number of invasive species occurrences. **Figure 4** illustrates a typical occurrence of *Sericea lespedeza*.

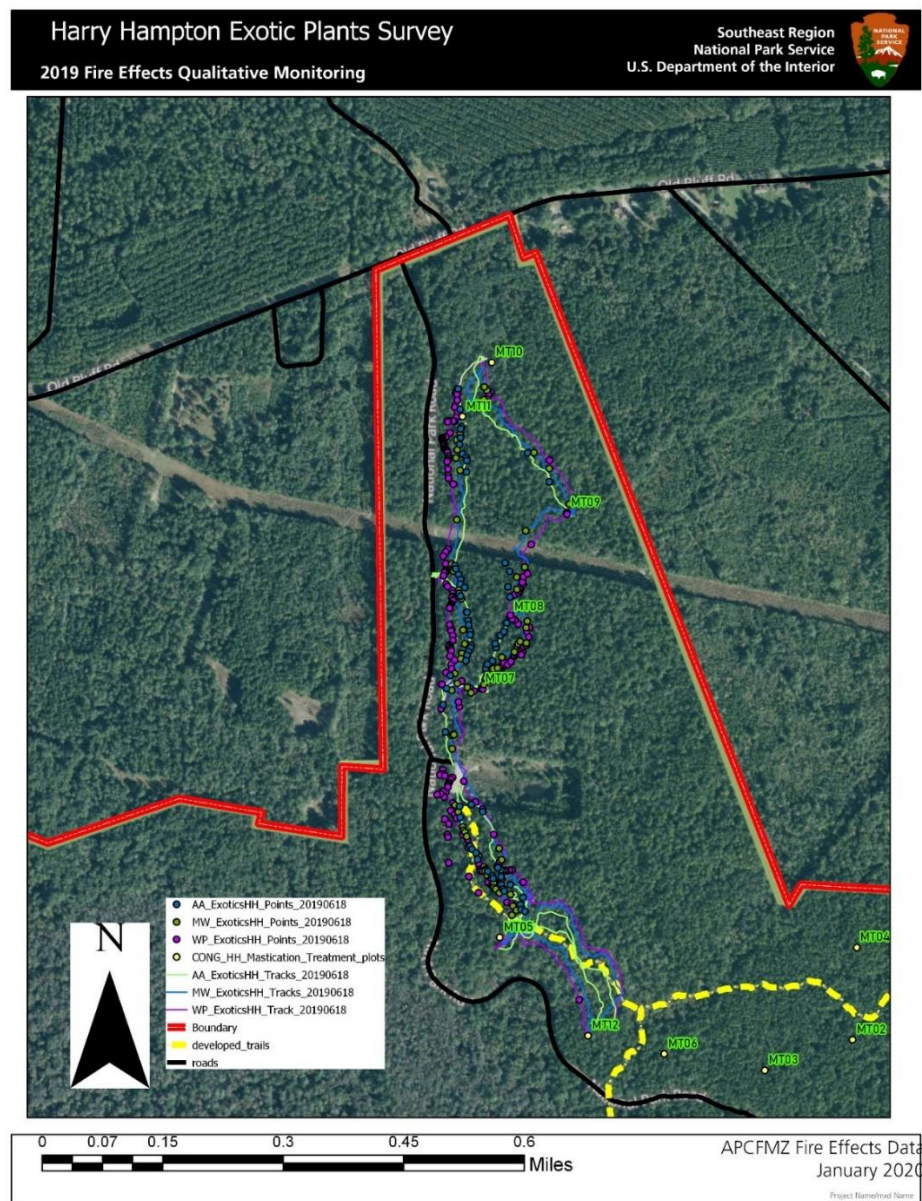


Figure 3. Map showing track logs and waypoints of invasive species surveys in Harry Hampton treatment unit.

Table 1. Summary of invasive plant encounters.

Name	Number of exotics points
AA – Individual	69
MW- Individual	76
WP- Individual	173

The individual tracks may have crossed slightly, but distance was kept to avoid re-sampling of exotic plant points. The data does not represent a complete survey of exotics throughout the unit, but the sample was provided data to the Coastal Exotic Plants team and the park. A process of collaborative management is believed to be the most successful technique. These areas are priority restoration areas therefore the control of invasive species is paramount in restoration and other management actions.

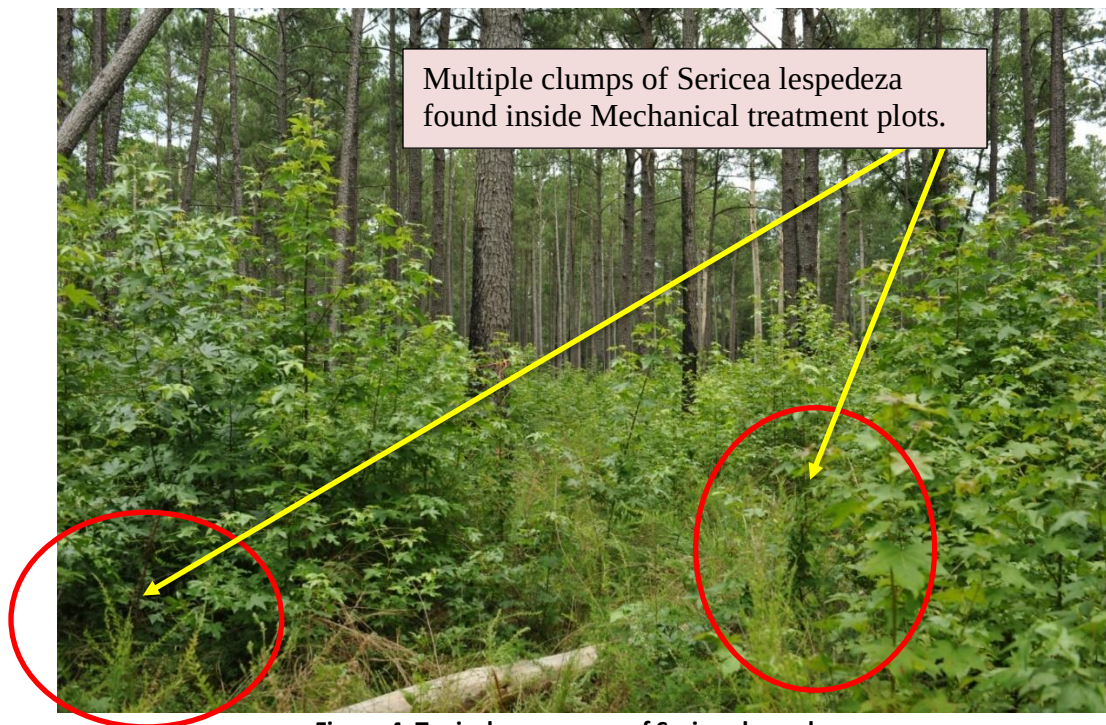


Figure 4. Typical occurrence of *Sericea lespedeza*.

Key Takeaways

- Large numbers of mimosa, *Sericea lespedeza*, and bushy lespedeza plants were found closest to main park drive and campground.
- Use of herbicide for sweet gum was effective, although could be targeted at *Sericea lespedeza* as well.
- Coordinated herbicide treatment and fire is needed for successful restoration.

Long Term Monitoring Results

Long term monitoring results were updated for last year's report (**Table 1**), and no additional data pertaining to these objectives was collected during 2019. These results are the most current.

Repeated from last year's report: Several key objectives have been achieved over the past 20 years of burning, though other objectives have not been met. This is most likely because the original objectives were created years ago, before Resource Managers and Fire Monitoring staff had adequate knowledge of what could be expected through multiple prescribed burns. A great deal has been learned from monitoring in that time, and better objectives can and should be created. Undoubtedly there is new research available that could also help to inform a new set of objectives. It is recommended that the Fire Ecologist and Park staff review both long and short term objectives for prescribed burning and monitoring in the coming year.

Table 1. Objectives and long-term monitoring results for CONG

Vegetation Type	Management Objective Restoration Phase- After ?? burns	Monitoring Results	Objective Achieved?	Year Last Analysis Completed
Longleaf/ Loblolly Pine Woodland (FPIPA1) 5 plots	>50% Reduction in total fuel loading	Fuel reduction - 7 burns: 10% (n=4 plots, 1 burn unit)	No. The objective needs to be changed	2019
	15-30% Reduction in overstory tree density	Overstory reduction - 10 burns: 16% (n=4 plots, 1 burn unit)	Yes	2019
	>200 tall (>1m) Longleaf pine seedlings /ac	Preburn density: data not clean After 8 burns: 4/acre (n=4 plots, 1 burn unit)	No*	2019
Loblolly Pine Forest (FPITA1) 5 plots	>50% Reduction in total fuel loading	Total fuel reduction - 5 burns: 20% (n=3 plots, 1 burn unit)	No. The objective needs to be changed	2019
	>70% Reduction in pole-sized tree density	Pole reduction – 8 burns: 87% (n=3 plots, 1 burn unit)	Yes	2019
	25-50% Reduction in overstory tree density	Overstory reduction – 8 burns: 28% (n=3 plots, 1 burn unit)	Yes	2019

* There are numerous longleaf seedlings within the core longleaf area and some additional seedlings near the Bluff Campground.

Cumberland Gap National Historical Park (CUGA): 2019 Fire Effects Monitoring Annual Report

Activity Summary

During 2019, the APC Zone fire effects team continued to provide fire ecology and fire effects monitoring services to CUGA, although planning and operations services are now provided by the Mississippi River Fire Management Zone. Our team made two visits to CUGA during 2019; the first to participate in the Harlan Road A prescribed burn, and then later in the summer to more closely examine the long-term effects of multiple burns on the fuels and vegetation in the Harlan A prescribed burn unit.

The burn and monitoring work for Harlan A are comprehensively described in the “*Review of 2019 Projects*” below. Results from long-term monitoring have not been updated for this year’s report due to lack of time. Updating these long-term results will be a top priority in the coming year. Long-term analysis of the trends in fuel loading through 15 years of prescribed burning at CUGA are also included in the analysis of Appalachian Highland parks that begins on **page 9** on this Annual Report.

Review of 2019 Projects

Harlan Road A Prescribed Burn:

Harlan Road is a 236 acre prescribed burn unit located east of Middlesboro, KY and just north of the actual Cumberland Gap. The unit is essentially a continuous stretch of steep slopes and spur ridges descending west to highway 988 from the high ground along the Harlan Road Trail on the east side of the unit. The forest is dominated by dry-oak species commonly including chestnut oak (*Quercus montana*) and scarlet oak (*Quercus coccinea*). Formerly yellow pines, including pitch pine (*Pinus rigida*), shortleaf pine (*Pinus echinata*) and Virginia pine (*Pinus virginiana*), were also co-dominant with oak on this landscape, but fire exclusion and the southern pine beetle (SPB) infestation in the early 2000’s has left only a scattering of individual across much of the unit.

The April 20, 2019 prescribed burn marks the third entry for this unit, with previous burn treatments in April 2008 and March 2012. Extended severity mapping for the 2019 burn indicated overall severity was ‘very low’ with a few small patches of ‘low’ severity which overlap previous canopy gaps (**Figure 1**). Observed fire intensity was generally moderate with complete consumption of oak leaf litter, high consumption of 1- and 10-hr fuels, and partial consumption of 100- and even 1000-hr fuels (**Photo 1**). As with previous burns, fire was allowed to back and flank from the high ground all day and overnight, reaching the bottom of the slope in many areas by the following morning, and resulting in a very complete burn of the unit. Jackpots of dry heavies along the east line resulted in a several small spots from midday on, along with one large 6-acre spot that required a couple hours to contain (area adjacent to the word ‘Dark’ in **Figure 1**).

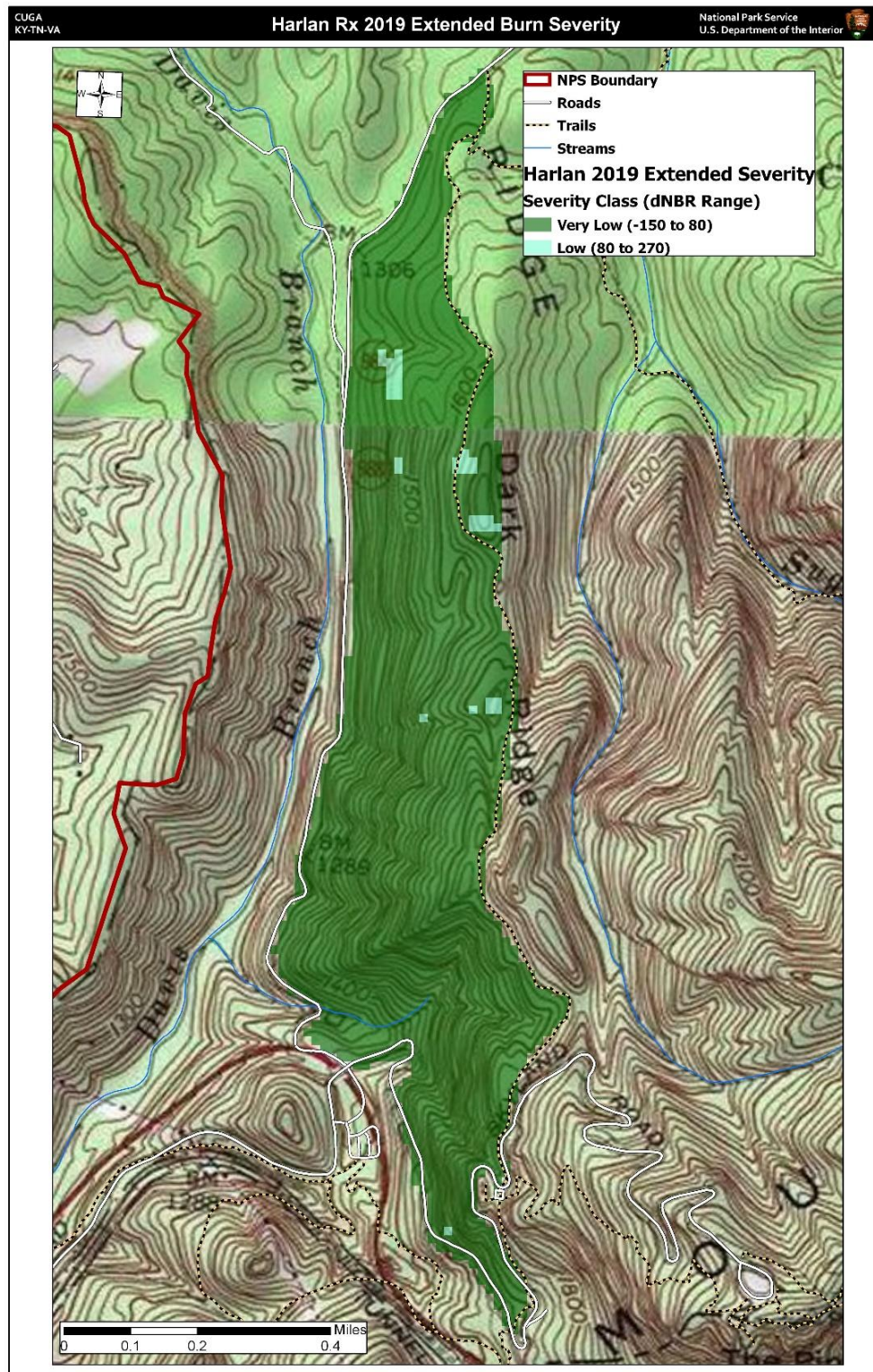


Figure 1. Extended burn severity map of 2019 Harlan Road Rx. Note that the majority of the unit is classified as ‘very low’ severity (dark green pixels) with a few spots of ‘low’ severity (aqua blue) that correlate to pre-existing canopy gaps.



Photo 1. Flanking fire burning through oak forest during the 2019 Harlan Road prescribed burn

Effects on the overstory were generally light, with char heights on tree trunks less than 2 feet high on average, and low mortality. Many of the smaller pole size trees and tall seedlings have been top-killed from previous burns so, despite moderate fire intensity, additional thinning in these vulnerable sizes was limited due to a lack of stems. Overall, fire intensity increased from midday on as ignition progressed from south to north, with some localized areas of higher char on poles and overstory around the slopover area.

This unit serves as a great model for long term fire restoration to a landscape, as the overstory oak has been retained while significant progress has been made to thin both the understory and lower midstory. FMH plot monitoring data from the Harlan Road unit shows almost no change in the overstory stem density from pre burn to the present (**Table 1**).

Burn Status	Total Average Trees/Acre
Pre Burn (2007)	144.7
1st Summer After 3rd Burn (2019)	141.6

Table 1. Table of FMH monitoring data from plots in the Harlan Road burn unit showing total average stems/acre for all overstory trees both pre burn and following the most recent 3rd burn treatment.

While very little change was detected, some small loss of overstory scarlet oak has occurred along with a similar recruitment of red maple (*Acer rubrum*) stems into the overstory from the pole size class resulting in some slight change in composition with little overall change in stem

density. Pole stem density has, however, seen *significant* changes from pre burn to present with and an overall **75% decrease** in total average number of stems/acre, and particularly noticeable decreases in density of encroaching fire intolerant hardwoods including red maple, black gum (*Nyssa sylvatica*), sourwood (*Oxydendrum arboreum*), and sassafras (*Sassafras albidum*) (**Table 2**).

Species	Pre Burn (2007) Stems/Acre	1st Summer After 3rd Burn (2019) Stems/Acre	Percent Decrease
Red Maple	182.1	36.4	-80.0%
Black Gum	85.0	24.3	-71.4%
Sourwood	32.4	4.1	-87.5%
Sassafras	40.5	0.0	-100.0%
Hickory	36.4	20.2	-44.5%
Chestnut Oak	12.1	8.1	-33.1%
Virginia Pine	8.1	4.1	-49.4%
All Poles	400.6	101.2	-74.7%

Table 2. Table of FMH data from Harlan Road monitoring plots showing the decrease in stems/acre of the most commonly occurring pole size trees from pre burn through the current 3rd entry.

While these data represent a significant reduction in less desirable pole size tree species, it is also obvious that further reduction of red maple and black gum is needed along with additional recruitment of oak and yellow pine. **Photos 2** and **3** provide a visual example of the stem density reduction captured in the monitoring data.

Repeated burning should help to further remove more of the remaining larger red maple and black gum poles as well as begin to gradually thin the overstory. Additionally, some poles and trees, particularly red maple, will likely decline over time even without burning due to prior basal wounding from fire and subsequent rot (**Photo 4**).

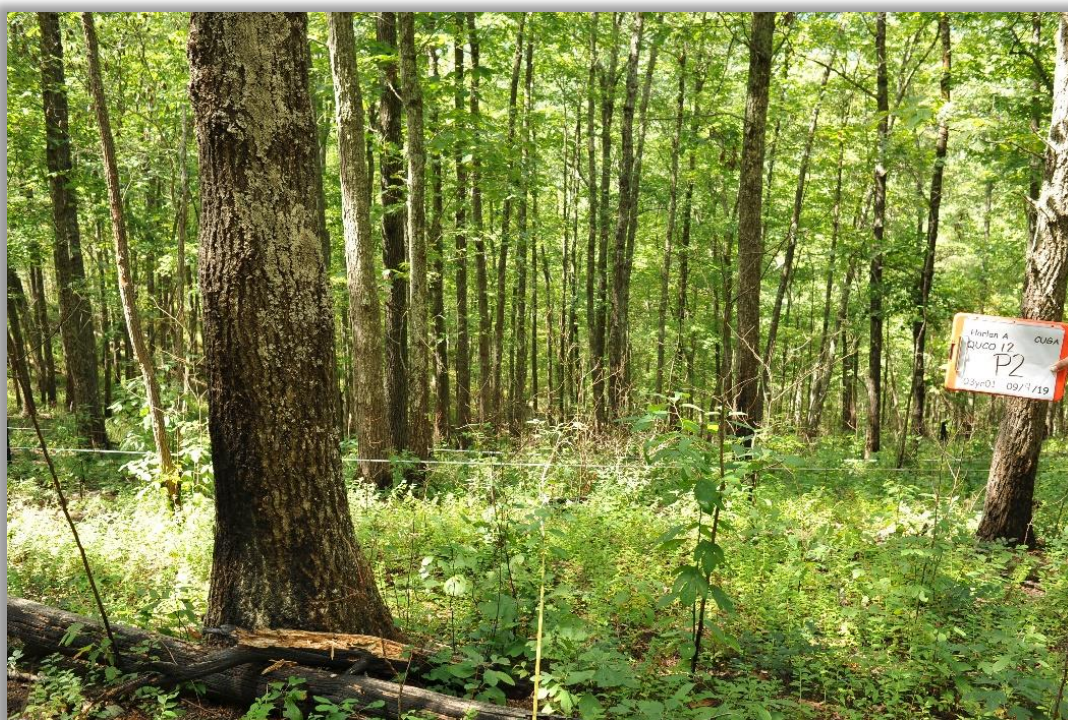


Photo 2 (top) shows relative pre burn stem density in a FMH plot in the Harlan Road burn unit (2007). Photo 3 (Bottom) show stem density at the same location as Photo 2 during the 1st summer following the most recent 3rd burn treatment (2019).



Photo 4. This photo illustrates the long term effects of basal damage on red maple stems commonly observed throughout the Harlan Road burn unit. Even though these trees are not immediately killed by fire, following wounding by fire the stems tend to develop severe rot and eventually break. This is an interesting and important facet of oak restoration.

While many of the upper slopes of the Harlan unit are structurally and compositionally similar to those observed in the FMH monitoring plots (oak overstory, thinned midstory and understory, and typically sparse ground cover), scouting of the unit during September 2019 also highlighted a couple xeric sites of interest. One location was in the slopover area (which also previously burned during the 2012 prescribed fire) in a canopy gap on a rocky slope above the trail. Interestingly, it contained some scattered pole and seedling size pitch pine and Virginia pine regeneration mixed with blackjack oak (*Quercus marilandica*) and a sparse scattering of little bluestem (*Schizachyrium scoparium*), creeping aster (*Eurybia surculosa*), and grass-leaved golden-aster (*Pityopsis graminifolia*).

Given this vegetation response and the fact that this has been a problem area operationally, it would be wise to adjust the unit boundary to include this ridge and any similar adjacent ridges that cause holding problems.

The other location of interest was on a steep slope midway between the highway and trail in the north end of the unit, just south of the last major drainage where the unit begins to narrow as the trail descends to meet the highway. This site was in a large canopy gap probably caused by the loss of yellow pine from SPB. The understory diversity here was greater than any other location observed in the unit with tree seedlings of blackjack oak, pitch pine, and Virginia pine and a low shrub layer including lowbush blueberry (*Vaccinium pallidum*) and black huckleberry (*Gaylussacia baccata*). Moreover the grass and forb cover included little bluestem, indiagrass (*Sorghastrum nutans*), tall nutrush (*Scleria triglomerata*), creeping aster, grass-leaved golden-aster, goat's-rue (*Tephrosia virginiana*), woodland coreopsis (*Coreopsis major*), fragrant goldenrod (*Solidago odora*), showy goldenrod (*Solidago erecta*), hyssopleaf eupatorium (*Eupatorium hyssopifolium*), Appalachian oak-leech (*Aureolaria levigata*), Virginia lespedeza (*Lespedeza virginica*), hairy lespedeza (*Lespedeza hirta*), bracken fern (*Pteridium aquilinum*), a tall species of *Chamaecrista*, and *Carex* species (**Photo 5 & 6**).



Photos 5 (top) and 6 (bottom) show examples of the general structure of a high diversity sight observed on the northern portion of the Harlan Road burn unit located in a former pine stand.

Unfortunately, clumps of Chinese silver grass (*Miscanthus sinensis*) were also observed this area. These locations were provided to CUGA resource managers soon after discovery. This will be an interesting area to watch over time as it may convert into a pine woodland. Moreover,

future scouting of this unit might help identify if any additional areas like this exist across the steep slopes of the unit interior. Monitoring and control of the Chinese silver grass going forward should also be a high priority.

Key Takeaway Points

- This unit is a great example of long term fire restoration in dry oak-yellow pine forest. The canopy has been maintained while significant progress has been made in thinning hardwoods in the midstory and understory, particularly red maple. Future burn planning could evaluate the possibility of using growing season burning and/or some carefully planned mixed intensity ignitions to further thin the midstory.
- Operationally it would be wise to adjust the east boundary to include adjacent ridges that have resulted in spot fires during previous burns.
- Some areas of modest yellow pine regeneration are present in canopy gaps formally associated with pine overstory lost to SPB. Moreover, herbaceous plant response in these areas is notable and further burning could result in an interesting woodland structure.
- Coordinated monitoring and control of Chinese silver grass should be a high priority going forward to prevent degradation of this burn site.

Long Term Monitoring Results

There has been no update to the standard analysis of long-term monitoring results. Consequently, **Table 1** has not been updated for this report, though we include it below as a reference point for reviewing the progress toward achieving program objectives.

Table 1. Results of long-term fire effects monitoring at Cumberland Gap NHP.

Vegetation Type	Management Objective Restoration Phase- (After 4 burns)	Monitoring Results (80% confidence intervals)	Objective Achieved?	Year Last Analysis Completed
Dry Oak Forest (FQUCO1) <i>16 plots</i>	>50% Reduction in total fuel loading	<u>Total Fuel Reduction:</u> After 1 burn (n= <u>16</u>): 29% (± 3) After 2 burns (n= <u>11</u>): 26% (± 2)	Not yet, but on course	2013
	>70% Reduction in pole-sized tree density ($\leq 15\text{cm dbh}$)	<u>Pole Reduction:</u> After 1 burn (n= <u>16</u>): 39% (± 5) After 2 Burns (n= <u>11</u>): 67% (± 3)	Not yet, but close	2013
	15-30% Reduction in overstory density ($>15\text{cm dbh}$)	<u>Overstory Tree Reduction:</u> After 1 burn (n= <u>16</u>): 5% (± 5) After 2 Burns (n= <u>11</u>): 8% (± 1)	Not yet, but on course	2013
	>200 tall ($>1\text{m}$) Oak seedlings /acre	Preburn (n=16 plots): 101/ac (± 12) After 1 burn(n=16): 91/acre (± 6)	Not yet.	2011
	>30% Cover by native herbs	Preburn cover (n=14): 2% ($\pm 1\%$) After 1 burn (n=14): 4% ($\pm 2\%$)	No, but more burns are needed.	2011
	< 20 Invasive exotic plants/acre	Preburn avg (n=16): 0/acre Post burn mean (n=16): 20/acre (± 14)	Unclear due to high variability.	2011

Note: An underlined sample size number indicates minimum plots exist for 80% Confidence Level.

Great Smoky Mountains National Park (GRSM): 2019 Fire Effects Monitoring Annual Report

Activity Summary

Support for the host park in 2019 focused on long-term plot monitoring of Lynn Hollow, Arbutus Ridge, Wash Ridge. Short term plot monitoring was completed at Short Bunk, which was burned for the first time in 2019. Additional monitoring was completed for the Ski Mt. mechanical fuel reduction project, Chimney Tops 2, and Happy Valley Ridge. An interesting short-term study was done of a historical fire called the Hickory Wildfire, which occurred on Bote Mt. in 1986. This fire occurred during a severe drought and resulted in stand-replacement in multiple stands of montane Table Mountain/Pitch Pine woodland. By studying the recovery of vegetation and fuels from this event, we hope to gain insights into the ecology of these types of fires in the Southern Appalachians that can help us understand the potential long-term effects of the Chimney Tops 2 wildfire. Several of these monitoring projects are more fully described in the “Review of 2019 Projects” section below. For those projects not included in this year’s report (Chimney Tops 2, Hickory Fire, Short Bunk Rx), additional work is needed, and those reports will be included in next year’s annual report.

Other 2019 accomplishments included:

- support and collaboration for fire-related research in the Park
- continued development of a large dataset of burn severity maps
- mapping all prescribed burn, mechanical treatments, and wildfires that occurred in 2019
- collaboration with Region 2 Fire GIS to create a detailed GRSM Wildland Fuels map
- leadership and collaboration with the GRSM Fuels Interdisciplinary Team
- support for the production of information-rich FMP Mapsheets
- strong support and participation in fire operations and fire training
- fire ecology training and information for Park staff, partners, and the public.

Review of 2019 Projects

Lynn Hollow Prescribed Burn and Long-Term Monitoring:

Lynn Hollow is a 240 acre prescribed burn unit located adjacent to the Top-of-the-World community in the western end of the Great Smoky Mountains National Park (GRSM). The general area is comprised of low elevation (1500’-2100’) ridges dominated by mixed dry oak and yellow pine forest. This unit is of particular importance due to the abundance of old growth oak and, most notably, shortleaf pine (*Pinus echinata*) in the overstory, a keystone fire adapted yellow pine species in decline across much of the upland southeastern US and locally limited to lower elevation yellow pine communities near the park boundary.

Moreover, fire dendrochronology research in this area has shown evidence for a frequent and persistent fire regime over the last ~300 yrs, referencing 200-300+ year old fire-scarred shortleaf pine including one individual from the 1600s. This information, combined with lack of shortleaf pine regeneration and buildup of hazard fuels adjacent to WUI areas on the north boundary due



Photo 1. Photo from the 2019 Lynn Hollow prescribed burn of fire above the east holding line

to 80 years of fire suppression, helped identify this as an important prescribed burn project in the late 1990s.

The initial burn treatment was limited to the northern portion of the current unit, with the burn occurring in June of 1999 under dry conditions resulting in notable duff consumption. Immediately following this initial burn a major southern pine beetle (SPB) outbreak resulted in significant loss of mature yellow pine across the park including many old shortleaf pine in the Lynn Hollow area which led to the creation of scattered canopy gaps and the release of resprouting hardwood seedlings in the understory.

After a lapse of 15 years, a second treatment was completed in March and April of 2014, expanding the original unit boundary to the current day 240 acres. This second burn resulted in significant understory impacts, top-killing much of the 6-10' tall hardwood resprouts that had established since the 1999 burn and significantly thinning encroaching white pine (*Pinus strobus*) and hardwood seedlings and poles in the newly added acres, but with only modest duff consumption compared to the 1999 burn. **Figure 1** shows the most recent March 18, 2019 burn perimeter with overlays delineating the June 1999 treatment and the 2014 March and April treatments.

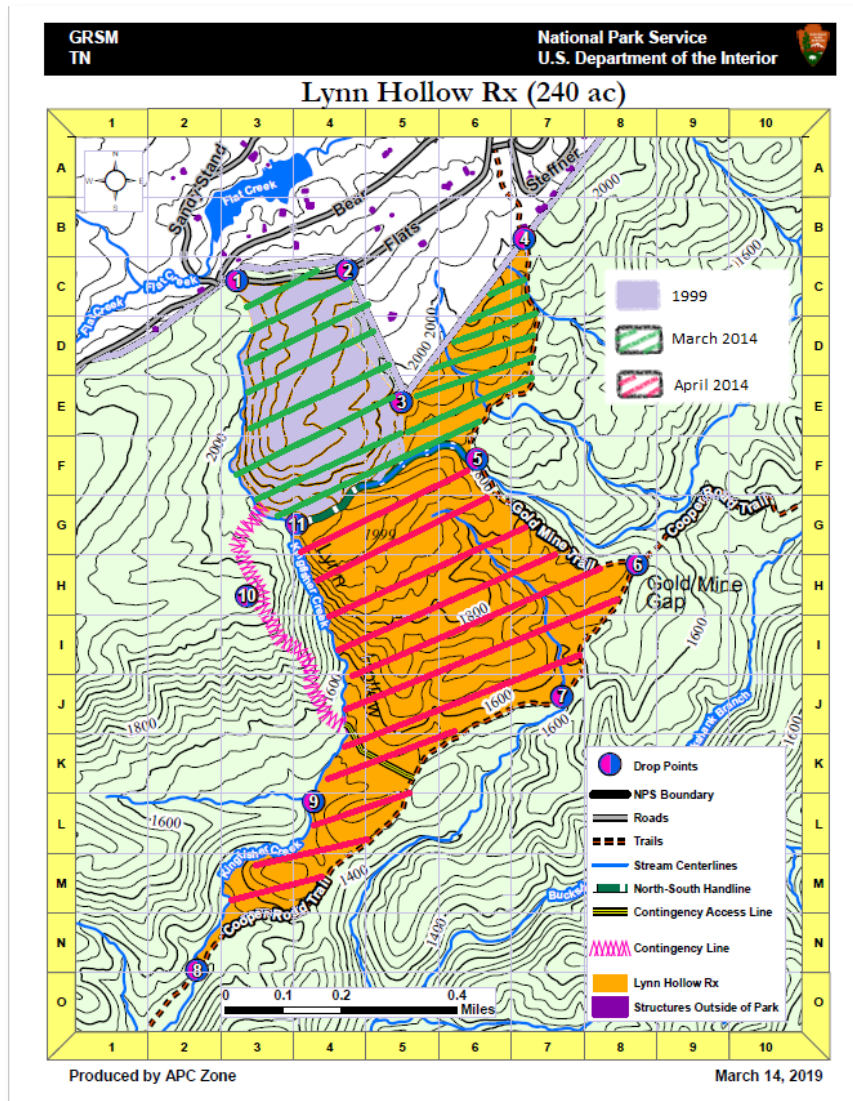


Figure 1. Map of 2019 Lynn Hollow prescribed burn perimeter with previous burns highlighted

Extended burn severity mapping derived from Sentinel-2 satellite imagery (**Figure 2**) indicated much of the 2019 burn received ‘very low’ to ‘low’ vegetation severity impacts. Additionally, areas of ‘low’ to ‘moderate’ severity in **Figure 2** represent pre-existing canopy gaps which were previously created due to a combination of steep dry topographic position, xeric vegetation including Virginia pine (*Pinus virginiana*) forest with flammable mountain laurel (*Kalmia latifolia*) understory, and canopy decline from SPB. Post burn scouting and FMH plot data collection during the growing season, likewise showed, much like the 2014 burn, very little impact to the overstory and midstory, with most of the impacts limited to top-kill of understory shrubs and tree seedlings and consumption of litter and 1-hr and 10-hr fuels. Duff consumption was again generally modest.

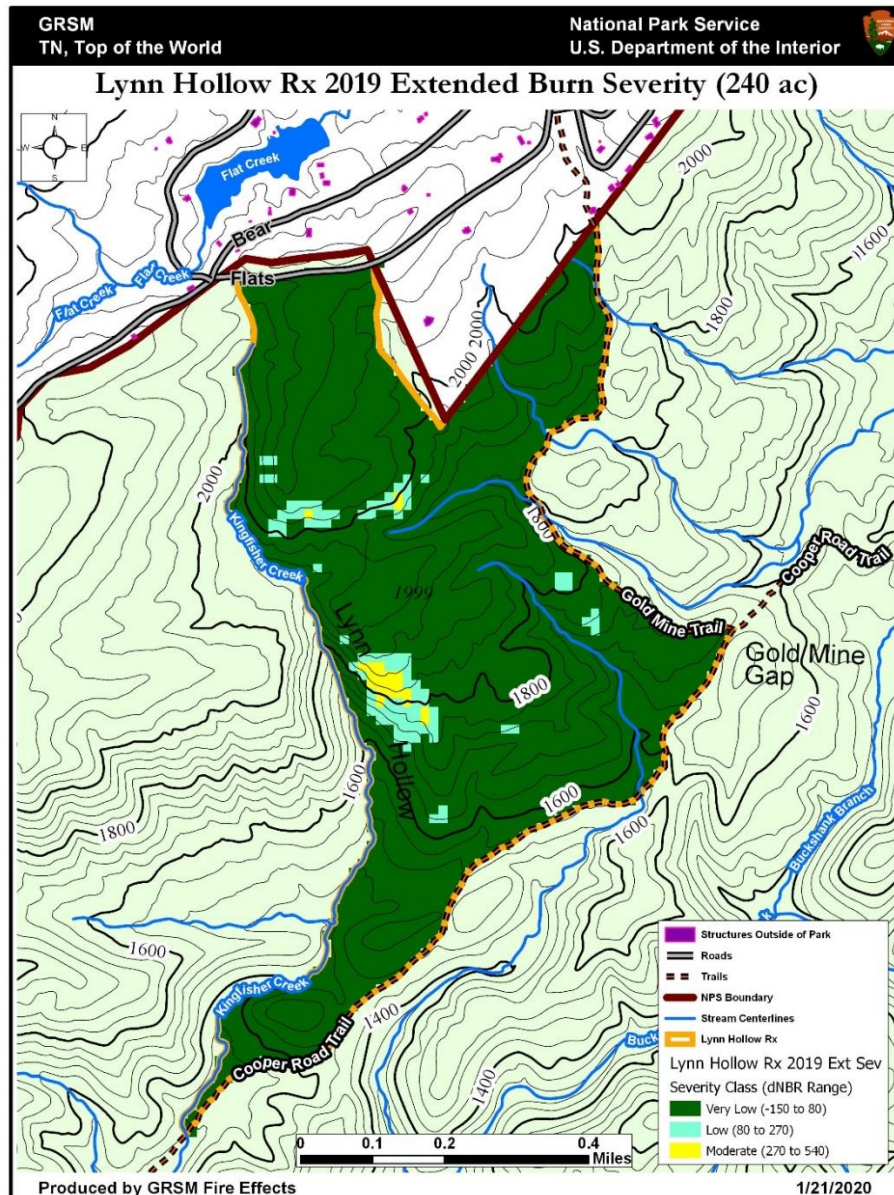


Figure 2. Map showing extended burn severity for the March 18, 2019 burn of Lynn Hollow. Dark green indicates very low severity, aqua blue is low, and yellow is moderate. Areas of low to moderate severity were restricted to prior canopy gaps.

Top-kill of encroaching hardwood resprouts was somewhat moderated compared to the 2014 burn, especially in the original 1999 section which was burned earlier in the day under elevated relative humidity and with a fast ignition tempo (**Photos 2 & 3**). The southern portion of the unit appeared to burn with comparatively greater intensity resulting in better top-kill of hardwood seedlings, although this portion of the burn had less hardwood resprout encroachment due to the shorter time interval between burns and less impacts from SPB leaving the canopy more intact.



Photos 2. This FMH plot photo from summer 2014 following the 2nd burn entry, shows an example of relative understory thinning in the original 1999 portion of the burn unit. Note the difference in visibility range from foreground to background in this photo compared to Photo 3 as well as the difference in sunlight reaching the forest floor.



Photo 3. This photo from summer 2019 following the 3rd burn entry, taken from the same location as Photo 2, shows an example of the reduced visibility range and greater shading relative to the 2014 burn due to lower burn intensity resulting in reduced top-kill of encroaching hardwood seedlings.

Overall, the short term objectives for this unit of reducing leaf litter, limiting overstory mortality of mature yellow pine and oak, and safely completing the operation were successfully met. *Moving forward, managing hardwood resprouts, particularly in the original 1999 north unit, should be a key objective.* At this stage, especially given the lighter burn effects from the recent burn, it will be important to re-burn the unit as soon as possible, preferably within the next 2-3 years, and additionally it would be advantageous to consider adding specific objectives to the IAP, particularly focused on the original north section, that address the need to maximize top-kill of hardwood seedlings without significantly compromising the overstory pine and oak seed source. Such objectives do appear to be in the burn plan but were not specifically addressed in the burn day IAP.

Regarding the long term objectives discussed in the burn plan, specifically the desire to regenerate yellow pine, some interesting progress has been made in the original north burn portion of the unit. As previously discussed, the 1999 burn was an early growing season burn which, as is more typical for burns of this seasonality versus dormant season, resulted in notable reduction of the duff layer, possibly as much as 50% removal, thereby creating a more favorable seedbed for yellow pine by reducing the depth of organic material covering the mineral soil. Additionally, FMH plot data captured a significant loss of overstory yellow pine from SPB in the shortleaf pine dominated portions of the unit with stems per acre of overstory yellow pine dropping from 113 to 4 by the 5th summer following the first burn. Given that this is a mixed oak and pine community, the resulting canopy gaps were generally small in size and well scattered across the unit. This combination of reduced duff and increased sunlight reaching the understory, while allowing the further proliferation and establishment of fire intolerant hardwoods and white pine over the intervening 15 years between the first and second burn, has also resulted in scattered pockets of yellow pine seedling establishment. **Table 1** shows the progress of yellow pine stem recruitment within the original north Lynn Hollow FMH plots.

Burn Status	Year	Avg # Stems/Plot <2 ft Tall	Avg # Stems/Plot >2 ft Tall	Total Avg # Stems/Plot
Pre Burn	1998	0.25	0	0.25
5th Summer After 1st Burn	2004	3.25	0	3.25
10th Summer After 1st Burn	2009	3.5	7.5	11
1st Summer After 2nd Burn	2014	7.5	4.75	12.25
5th Summer After 2nd Burn	2018	2	1.75	3.75
1st Summer After 3rd Burn	2019	11.5	0.5	12

Table 1. This table shows the recruitment of yellow pine seedlings in FMH plots located within the original Lynn Hollow burn. Note that the table has columns separating counts for the smallest size classes (< 2ft tall) from all other size classes, as well as a total of all sizes.

There was a clear progression following the first burn from almost no seedlings present to the establishment and growth of several stems across all size classes by year 10 after the first burn. The increase of stems in the smaller size classes immediately following the second and third burns was actually primarily detecting the resprout response of shortleaf pine following the subsequent burns rather than true significant additional recruitment of new individuals. Anecdotally, the first summer following a burn resprouting individual shortleaf stems can have 5 or more coppice sprouts, all less than 2 feet tall, typically however, one of these sprouts tends to be clearly taller than the rest and over the next 5 years often becomes the dominant stem with other sprouts declining and dying (**Photo 4**).



Photo 4. Example of a typical resprouting shortleaf pine seedling.
Note one of the sprouts is already asserting dominance.

Additionally, the simultaneous decrease in stems in the larger size classes is explained both by the advancement of several shortleaf and Virginia pine stems into the pole size class and the death of some Virginia pine (which does not resprout and prefers less frequent fire generally being more easily wounded or killed when young) particularly following the intensity of the second burn. **Table 2** shows the recruitment of yellow pine stems from seedlings into pole size trees over time.

Burn Status	Year	Avg # Stems/Acre
Pre Burn	1998	4.0
10th Summer After 1st Burn	2009	32.4
1st Summer After 2nd Burn	2014	76.9
1st Summer After 3rd Burn	2019	80.9

Table 2. This table shows the average stems per acre of pole size yellow pine based on FMH plot data collected within the original Lynn Hollow burn area from pre burn to present.

Proportionally, shortleaf pine accounted for only 20% of the current pole size stems with Virginia pine comprising the remaining 80%. The original FMH plot overstory composition was almost the opposite with shortleaf accounting for over 85% of the stems and Virginia pine the remainder. Currently, yellow pine is almost completely absent from the overstory within the plots but it is present adjacent to some of the plots with a few mature shortleaf and occasion Virginia pine still scattered throughout the north portion of the burn. It is typical for Virginia pine to show a prolific response to disturbance events such as the duff reduction of the 1999 burn coupled with canopy gap creation due to SPB. This initial response along with the loss of so many shortleaf pine seed trees and a 15 year fire free interval likely explains the current composition of the pole size class. Over time, especially with repeated burns, it is possible Virginia pine will be further thinned from the poles and that future recruitment will favor shortleaf pine especially considering the current cohort of pine seedlings observed during the 2019 FMH plot reads was exclusively shortleaf.

In contrast, FMH plot data from the southern portion of Lynn Hollow, which has burned twice under dormant season conditions, has shown no yellow pine recruitment into the seedling or pole size classes despite having live shortleaf pine in the overstory. Generally, the canopy remains intact in this area with very little gap formation due to fire and comparatively less loss from SPB relative to the original north burn. Most importantly, the duff layer has not been significantly reduced from pre burn conditions, severely limiting the ability of yellow pine seedlings to become established. Hence, a comparison of the original north Lynn Hollow burn with the newer southern addition tentatively points to the need to incorporate growing season burning into the long term management strategy for this unit to facilitate the objective of yellow pine regeneration.

Increasing herbaceous species abundance and diversity is another important long term goal for this unit, but it has proved more difficult than yellow pine regeneration. While species diversity within the Lynn Hollow FMH plots is fairly high, understory cover is largely dominated by woody species, especially blueberries (*Vaccinium* spp.) such as hairy blueberry (*Vaccinium hirsutum*) which typically forms a low growing carpet across the forest floor particularly where there is a significant duff layer. A few persisting native grass species, especially little bluestem (*Schizachyrium scoparium*) and occasionally indiagrass (*Sorghastrum nutans*), have shown

some slight expansion particularly in light gaps along some of the steeper rocky slopes in the northern section (**Photo 5**).



Photo 5. Grass response along a steep rocky slope on the west side of the north unit.

Some showy species, including pink lady's-slipper (*Cypripedium acaule*), Carolina lily (*Lilium michauxii*), and American lily-of-the-valley (*Convallaria pseudomajalis*), that were present pre-burn and which generally appear to persist longer in absence of fire, have also shown positive response following burning, notably after the 2014 burn when numerous individuals were observed to flower. Interestingly, a rare sighting of large whorled pogonia (*Isotria verticillata*) was observed in April 2019 in one of the original north unit FMH plots (**Photo 6**).



Photo 6. Rare sighting of large whorled pogonia in the north unit.

Generally, however, the bulk of native herbaceous plants and grasses are restricted to the unit boundaries along trail sides and road shoulders where they are inadvertently maintained through annual mowing. While removal of the duff layer, increasing sunlight transmission to the forest floor through gradual and dispersed canopy removal, and reduction of woody competition in the understory should create the desired conditions to favor herbaceous diversity in the understory, it is becoming obvious that, much like yellow pine regeneration, this will require particular seasonality as well as frequency with future applications of fire. Moreover, across much of the site no seedbank or rootstock remains for many of the species of interest, requiring a long term process of expansion from trail and roadside seed sources.

Key Takeaway Points

- Moving forward there is a critical need to manage hardwood resprouts, especially in the north unit, by maintaining frequent burn treatments (every 2-3yrs) and using a focused and well planned ignition strategy that maximizes top-kill of resprouts without significant loss of overstory seed trees
- Longer term, incorporating early growing season burning (May and June) will be important to further reduce duff to facilitate establishment of shortleaf pine and herbaceous species that are currently absent from much of the unit. This is a long term process that should be played out over multiple burns with intentional planning, evaluation, and adjustment.

Happy Valley Ridge WF Long Term Effects:



Photo 7. Smoldering fire consuming the deep duff buildup immediately around the base of and nearby a mature shortleaf pine during the September 2016 Happy Valley Ridge Wildfire.

The Happy Valley Ridge wildfire was a 134 acre fire that occurred in September 2016 on the northwest boundary of GRSM just west of the Lynn Hollow prescribed burn unit discussed above. Persistent drought conditions leading up to and during the fire made control difficult due to the extreme dryness of duff, 1000-hr fuels, and snags, with KBDI (Keetch-Byram Drought Index) numbers ranging from 564-583 (index scale is 0 to 800 with 800 being the most severe drought conditions) during the period of active growth. Initial attack on 9/15/16 proved unsuccessful leading to a combination of direct and indirect line construction along with use of stream corridors and changes in fuel type to contain the fire and hold it along the park boundary areas by 9/18/16 in conjunction with a rain event. The fire was monitored over the next few days as limited growth continued within the park with the majority of expansion finished on 9/23/16 and the final area of perimeter growth actively checked with handline on 10/10/16.

This burn area shares very similar topographic position and mixed dry oak-yellow pine forest composition to the nearby Lynn Hollow burn unit, with numerous mature living shortleaf pine observed across the ridges and upper slopes during the wildfire. The uncertain long term effects of the deep duff consumption that occurred during the burn, especially around the base of mature shortleaf pine where it tends to build up in a thick ‘doughnut’ ring, provided an interesting opportunity for comparison with the prescribed burn effects measured in the Lynn Hollow unit. Extended burn severity mapping derived from Sentinel-2 satellite imagery showed overall low severity with a few significant blocks of moderate and high severity on south and west facing slopes and spur ridges (**Figure 3**). Field scouting of the burn in early October of 2019 provided to opportunity to ground truth this severity map and compare the effects of late growing season fire in this oak-shortleaf pine community with the early growing season and dormant season prescribed burns in the similar forest community at Lynn Hollow.

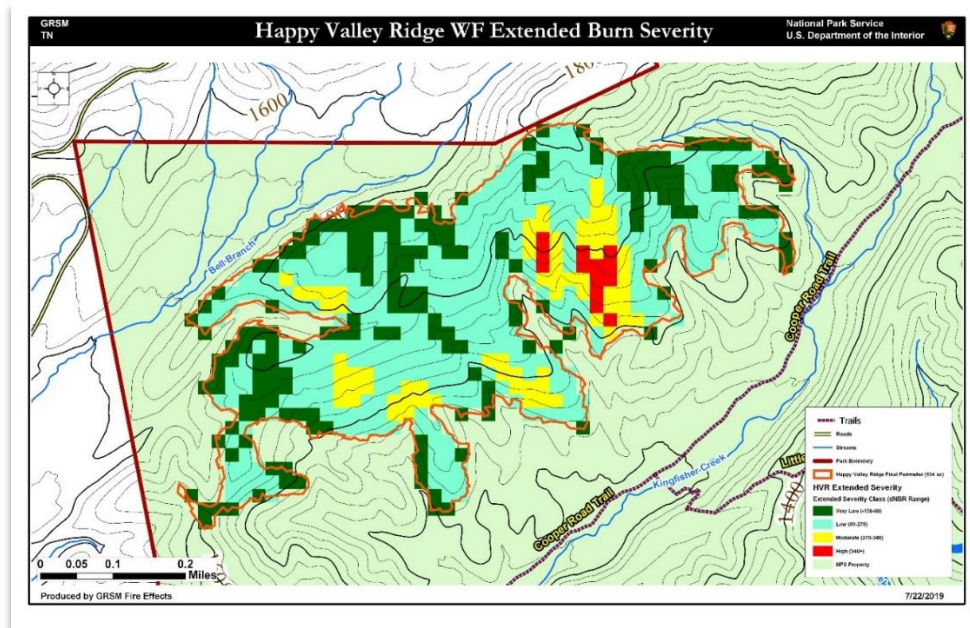


Figure 3. Extended burn severity map of the 2016 Happy Valley Ridge wildfire. Note that much of the burn resulted in low severity (aqua blue) but some significant patches of moderate (yellow) and high (red) severity also occurred.

Overall duff consumption appeared to be 80-100% across much of the burn often leaving patches of bare mineral soil and rock. Low growing shrubs such as blueberries and huckleberries (*Gaylussacia* spp.) appeared to be severely reduced in cover due to loss of root systems that were formerly invested in the duff layer. Additionally, despite moderate to high increases in sunlight transmission through the thinned overstory and midstory, hardwood resprouts did not dominant the understory but rather often appeared scattered and patchy in distribution, interspersed with bare ground and sparse low shrubs (**Photo 8**).



Photo 8. 2019 photo from Happy Valley Ridge showing a transitional low/moderate severity area with patches of bare soil and rock, scattered hardwood resprouts, and almost no shrub cover



Photo 9. Example of a very low severity area along the main ridgeline of HVR that burned early on during initial attack. Note the intact overstory, thinned midstory, and open but shaded understory with sparse hardwood re-sprouts. Duff consumption in this area was not as severe with fewer patches of bare ground and more sprouts of low shrubs.

Low severity (aqua blue on Figure 3) had variable overstory mortality ranging approximately from 10-60% and high midstory mortality with roughly 40-100% loss. These areas tended to have notable patches of bare ground with occasional sparse cover of low shrubs and scattered hardwood resprouts (**Photos 10 & 11**).

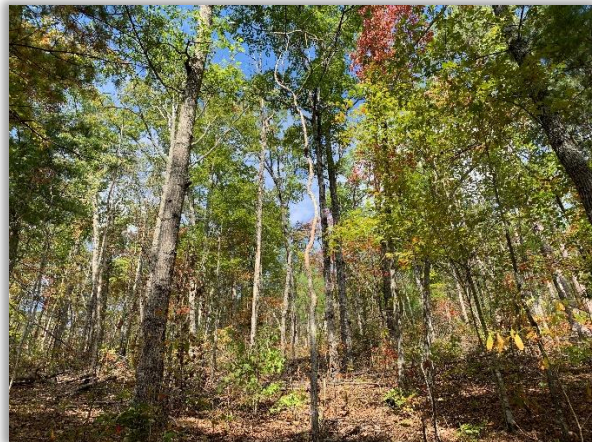


Photo 10 (left) Shows understory effects in a low severity area, note the patches of bare ground, sparse low shrub cover and scattered hardwood resprouts. **Photo 11 (right)** Shows overstory and midstory thinning in a low severity area.

Moderate severity (yellow pixels in Figure 3) areas typically had 75% or great overstory mortality with little or no midstory remaining. The understory of these areas was commonly dominated by pioneer weeds especially common dog-fennel (*Eupatorium capillifolium*) and fragrant rabbit-tobacco (*Psuedognaphalium obtusifolium*). Interestingly, in one area sourwood (*Oxydendrum arboretum*) had seeded in post fire forming dense patches of seedlings (**Photo 12**). Cover of low shrubs was often absent and hardwood resprouts were broadly scattered. Duff removal was almost complete and bare mineral soil and rock were common, but becoming overgrown with the colonizers mentioned above. Additionally, high severity (red pixels in Figure

3) sites generally had little or no remaining canopy and bare ground now dominated by dog-fennel and rabbit-tobacco (**Photo 13**).



Photo 12. (top) Moderate severity area with high canopy removal. Note the red leaves of sourwood seedlings and the tall feathery-leaved dog-fennel that have colonized the bare soil post burn. Photo 13 (bottom) High severity site with almost no remaining overstory and a dense dog-fennel and rabbit-tobacco understory.

Shortleaf pine survivorship and regeneration was the key long term point of interest investigated during the October 2019 scouting trip. As seen in the initial Photo 7, in the absence of frequent fire duff tends to build up in a thick ring around the base of shortleaf pine and when burned under dry conditions, this ring can completely consume potentially resulting in cambial damage

to the tree and significant loss of feeder roots. During the fire, complete consumption of these duff rings was observed on all mature shortleaf pine encountered within the burn (**Photo 14**).



Photo 14. Example of complete duff removal around the base of a mature shortleaf.

A brief scout of the burned area in the April 2017 tentatively indicated some survivorship but the recent 2019 scouting proved otherwise, as nearly every mature shortleaf pine encountered was dead or dying, regardless of the surrounding burn severity (**Photo 15**).



Photo 15. Group of dead overstory shortleaf pine surrounded by surviving oaks in a low severity area

Despite this loss scattered pine regeneration was observed throughout much of the burn, particularly near many of these dead stems. While most of these seedlings appeared to be shortleaf, both pitch pine (*Pinus rigida*) and especially Virginia pine were common. Generally, the coverage of yellow pine seedlings was low in most areas as seen in **Photo 16**, however the eastern spur ridge with the largest block of high and moderate severity had some noticeably

denser patches scattered along much of its length, often mixed with dog-fennel and rabbit-tobacco (**Photo 17**).



Photo 16 (top) shows an example of the sparse distribution of yellow pine seedling (note the seedlings circled in red) common across much of the site, while Photo 17 (bottom) shows a relatively dense patch of regeneration observed in the largest block of high severity.

This wildfire along with the 1999 early growing season and subsequent 2014 and 2019 dormant season prescribed burns at Lynn Hollow represent a spectrum of potential fire effects based on seasonality (which typically determines the possible upper range of dryness at different points

throughout a given year). When considering the use of prescribed fire or even the management of a wildfire to regenerate yellow pine in a forested system with high duff buildup, it seems clear that significant duff removal will be vital to meeting that objective. However, the complete removal of duff in a single burn as observed at Happy Valley Ridge is likely not ideal given the almost wholesale loss of seed trees. This scenario has been successful in montane yellow pine systems in the park, most notably with table mountain pine (*Pinus pungens*) in the Chimney Tops 2 wildfire of 2016 where many of the former pine stands are now a thick carpet of table mountain pine seedlings despite the complete loss of overstory. Virginia pine and to some lesser degree pitch pine can also respond with a single prolific seed release under certain moderate to high severity burn events, but shortleaf pine, while at times a prolific cone producer, seems to be more successful at seeding into a receptive seedbed and establishing dominance over the course of multiple years following a significant burn event as partially observed in the north portion of Lynn Hollow where Virginia pine largely dominated the initial cohort of seedlings while shortleaf was present in lesser numbers but has persisted through subsequent burns. Moreover, this strategy seems to better match the frequent fire regime suggested by the dendrochronology research done at Lynn Hollow. So, first and even second entry burns in a dry oak-shortleaf forest communities with heavy duff accumulation should preferably occur during the dormant, or perhaps more ideally, the early growing season so that duff consumption is moderated during any single burn event, with gradual reduction over the course of 2 to 3 burns or more if needed. Given a scenario such as the 1999 Lynn Hollow burn where duff is moderately consumed but some overstory shortleaf is retained post burn (ideally a majority in the absence of SPB), it is conceivable that a subsequent burn of the area under conditions similar to the Happy Valley Ridge wildfire could actually result in a net positive outcome because removal of the remaining duff might not have the same dramatic effect on overstory shortleaf especially if duff ring buildup was previously thinned. Additionally, with some shortleaf regeneration established prior to such a wildfire occurring it is possible, given shortleaf pine's ability to resprout, that it could quickly assert dominance post burn.

Key Takeaway Points

- While late growing season fires like the Happy Valley Ridge wildfire can certainly result in shortleaf pine regeneration, they are probably not the ideal scenario for a first entry burn. However, coupled with prior burn treatments such as early growing season burning, a late growing season prescribed burn or wildfire could favor pre-existing pine regeneration as well as aid in establishment of new seedlings.
- A more precise understanding of how KBDI correlates to past wildfire and prescribed burn events could make it a powerful predictor of severity, specifically duff consumption, thereby making it more useful in planning future prescribed burns treatments, particularly during the growing season when drought conditions are typically more common.

Cades Cove 2019:

In calendar year 2019, Cades Cove received the most attention on record with regards to fuel treatments since the start of the fire program. There were 8 burns planned for FY19/FY20 and all were completed. There were 4 completed in the spring and 4 in the fall with 1 re-burn of Cemetery Marsh that included the large woodlot along the loop road.

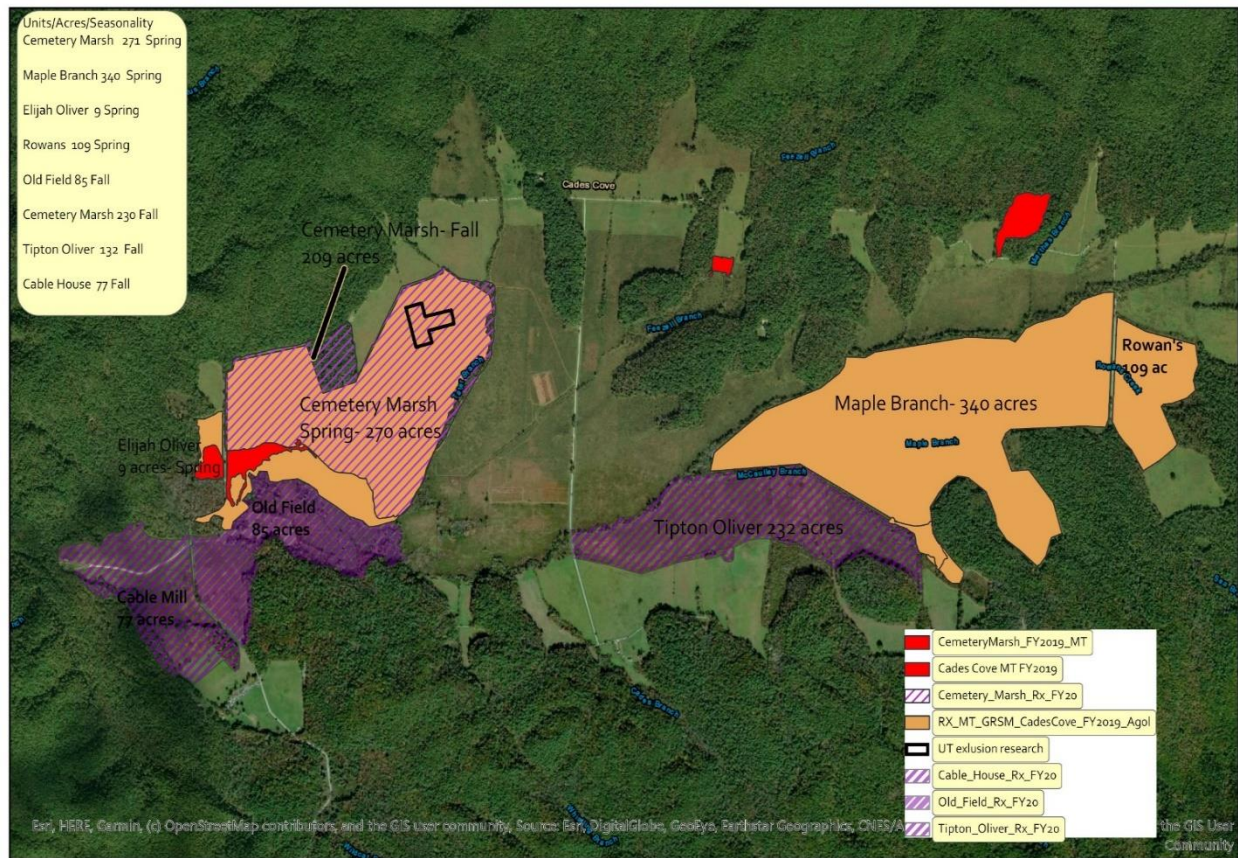
Several very important mechanical treatments took place as well. These mechanical treatments were completed with a skid steer- masticator by Eric Worthington during the later summer. The mastication work reestablished former open fields that had grown into thickets of hardwood trees such as sweet-gum (*Liquidambar styraciflua*) and tulip-poplar (*Liriodendron tulipifera*).



Figure 5. Old Field smoke column as seen from Gregory Bald- (GRSM volunteer)

Table 1. Summary of Treatments

<i>Unit</i>	<i>Acres</i>	<i>Seasonality and Number of burns</i>
Cemetery Marsh	~271 acres	Spring (6 burns)
Elijah Oliver	9 acres	Spring (3 burns, 1 MT)
Maple Branch	340 acres	Spring (3 burns, 1 partial MT)
Rowan's	109	Spring (3 burns)
Cemetery Marsh(with Woodlot)	209	Fall (7 burns / 1 st burn of woodlot)
Old field- upper and lower	85 acres	Fall (10 burns, 1 MT)
Tipton Oliver	232	Fall (5 burns)
Cable Mill	77 acres	Fall (6 burns)
Mechanical Treatments- Martha's		
Cemetery Marsh	10.3 acres	Summer
Maple	8 acres	Summer- Lower unit
Primitive Baptist	5.1 acres	Summer- Southeast section
Elijah Oliver	2 acres	Summer NE section
	4.1 acres	Summer



Produced by Fire Effects

2019 APC Fire Effects NPS Park Data

Figure 2. Red polygons indicate Mechanical treatments; Hashed lines indicate fall burns; and solid yellow indicates spring burns

Spring Burns:

In general the spring burns tended to have more moisture in the low lying areas of each unit, but coverage and objectives appear to have been met. Unit specific conditions remained the same throughout the spring although drier RH days with more wind consumed more fuels and covered more area in each unit.

Cemetery Marsh unit had the UT research block, which remained unburned, and the southern part of the unit was not burned. No woodlots were burned. Other units burned in the spring are noted within Table 1.

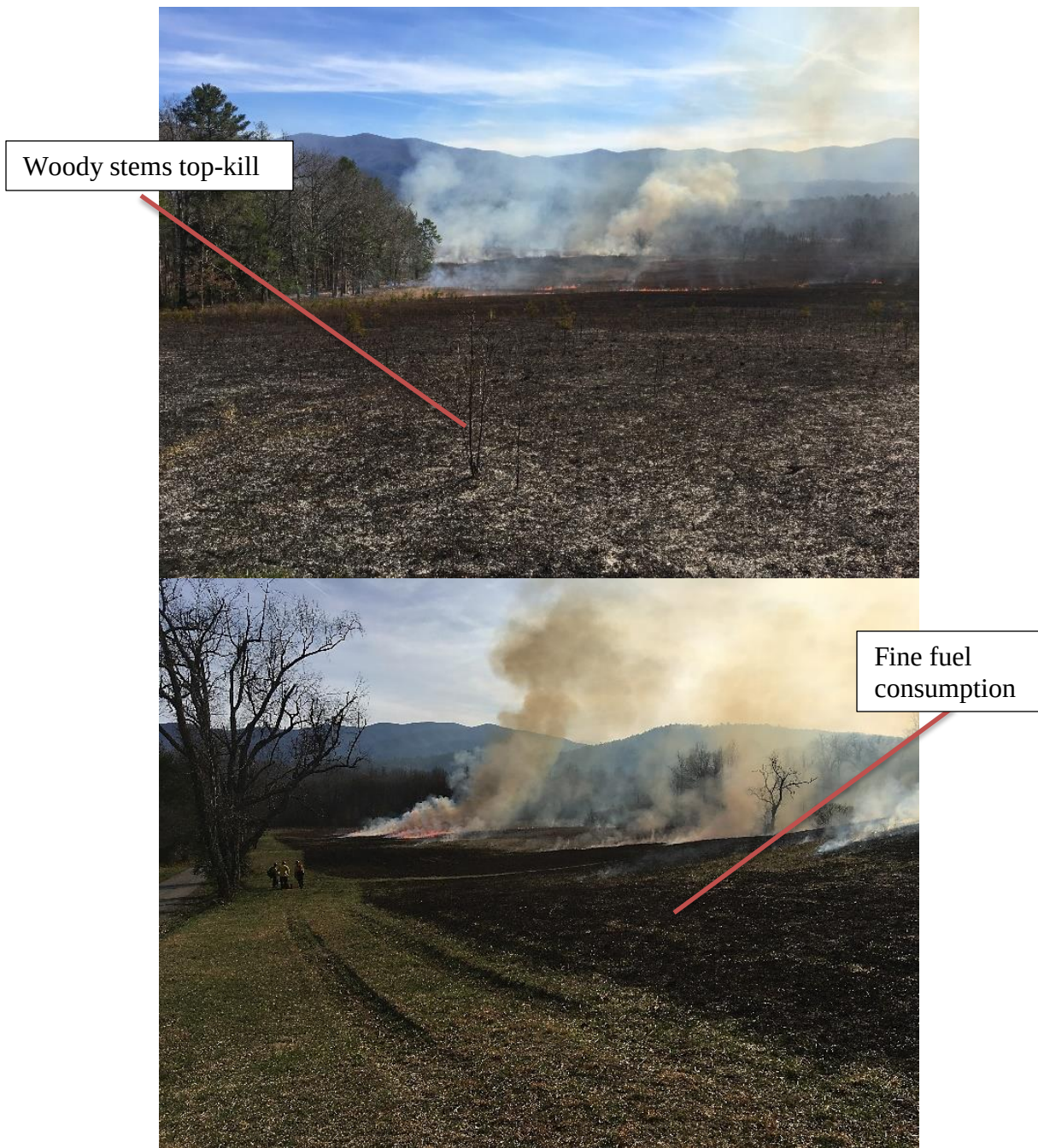


**Figure 3. Top: Spring burn of Cemetery Marsh. Top-kill of woody stems
Bottom: Elijah Oliver Rx. Showing coverage of burn and consumption of fine fuels. (Photo Drew Carles)**

Fall burns:

For **Old Field** and **Tipton Oliver** burns, the lack of wind proved to be a detriment in moving fire through the units. Upper Old Field burned more completely and with greater consumption than the lower section, but maintained patches of standing herbaceous stalks such as goldenrod (*Solidago sp*) and wing-stem (*Verbesina*). The lower Old Field section was sheltered from the wind and the apparent two killing frosts that occurred prior to the burn, resulting in some unburned patches and a greater amount of incompletely burned stalks.

A significant step was made burning the **Cemetery Marsh** in the same calendar year and burning the larger woodlot (1st entry) at the north end of the unit. In the past, burning woodlots in the cove produced a smoke annoyance issue with visitors and staff. The fall burn addressed the issue by introducing fire into the woodlot, and then quickly dealing with most mop up. Heavy fuels continued to burn for several days, but the burn boss assigned staff to mitigate any hazards.

The **Cable Mill** burn included all of the woodlot, where heavy fuels were seen being consumed by fire. Significant sections of sweet gum were top-killed by wind-driven fire into moderately thick sweet-gum stands.



Figure 4. Upper Old Field with residual grass and forb stalks.



Figures 5 & 6. Left: Cable Mill sweetgum top-kill. Right: Consumption of snags. (M. Wood)



Fire activity in the lower part of Old Field was limited to short duration runs in stands of cured grass.

Char on young, coppiced tulip poplar. Tipton Oliver unit.

Figure 7. Top: Lower Old Field. Bottom: East End of Tipton Oliver (Photo: Matt Wood)

Objectives for fall burns seem to have been met in terms of coverage of the burn and light fuel consumption. Scorch of woody stems in most units seemed successful where the stems occurred

in the middle of the field, but was minimal where stem density was high. Mechanical treatments may be needed in these areas of high stem density.

Mowing/Mulching –Martha’s Branch:

Another successful year occurred in the cove with regards to using a skid steer and mulching head, as well as tractor and bush hog. Much of the work occurred at the Martha’s Branch Unit. The effectiveness of these treatments at re-opening fields can be seen below in the before and after photos. Significant reduction of tulip poplar (*Liriodendron tulipifera*) and Black locust (*Robinia pseudoacacia*) stems < 6” dbh was completed by the end of FY19. Objectives of reclaiming over-grown fields in these units was successful as a one-time treatment, but continual attention will be needed to maintain fields.



Figures 8 &9. Martha’s fuel reduction comparison before (left) and after (right). (Photo: Eric Worthington)

Long Term Monitoring Results

No updates have been made to the long term monitoring results for this report. Most of Table 2 was updated in 2018, and no new analysis was completed for this year’s report. *A goal for next year’s report is to revamp this table and provide a clearer way to engage with the results of long-term monitoring of prescribed burns.*

Table 2. Objectives and long-term monitoring results for GRSM

Monitoring Type	Management Objective Restoration Phase- (After 4 burns)	Monitoring Results (80% confidence intervals)	Objective Achieved?	Year Last Analysis Completed
Yellow Pine Woodland (FPIR1) <i>29 Total Plots :</i> <i>28 have burned once</i> <i>17 have burned twice</i> <i>5 have burned three times</i> <i>1 remains unburned</i>	>50% Reduction in total fuel loading	<u>Total fuel reduction:</u> After 1 burn (n=27): 34% ($\pm 7\%$) After 2 burns (n=16): 37% ($\pm 6\%$) After 3 burns (n=5): 15% ($\pm 26\%$)	Insufficient data. <i>Objective may need to be revised.</i>	2018
	>70% Reduction in pole-sized tree density	<u>Pole reduction:</u> After 1 burn (n=28): 51% (± 8) After 2 burns (n=15): 77% (± 6) After 3 burns (n=5): 60% (± 27)	Insufficient data. But trend is positive.	2018
	25-50% Reduction in overstory tree density	<u>Overstory reduction:</u> After 1 burn (n=28): 18% (± 7) After 2 burns (n=15): 50% (± 13) After 3 burns (n=5): 10% (± 18)	Insufficient data.	2018
	>200 tall (>1m) Yellow Pine seedlings /ac	<u>Yellow Pine Seedling Density:</u> Preburn density (n=28): 0 After 1 burn (n=24): 631/ac (± 300) After 2 burns (n=15): 1237/ac (± 849) After 3 burns (n=5): 130 (± 198)	Insufficient data. But trend is positive. High variability.	2018
	>40% Cover by native herbs/subshrubs	Preburn cover: 3% ($\pm 1\%$) (n=23) After 1 burn (n=23): 11% ($\pm 4\%$) After 2 burns (n=9): 10% ($\pm 6\%$)	Insufficient data.	2009
Dry Oak Forest (FQUCO1) <i>24 total Plots :</i> <i>17 have burned once</i> <i>10 have burned twice</i> <i>5 have burned three times</i> <i>7 remain unburned</i>	>50% Reduction in total fuel loading	<u>Total Fuel reduction:</u> After 1 burn (n=15): 29% (± 4) After 2 burns (n=7): 27% (± 17) After 3 burns (n=5): 26% (± 18)	Insufficient data. <i>Objective may need to be revised.</i>	2018
	>70% Reduction in pole-sized tree density	<u>Pole reduction:</u> After 1 burn (n=17): 45% (± 10) After 2 burns (n=9): 49% (± 13) After 3 burns (n=5): 77% (± 16)	Insufficient data. But trend is positive.	2018
	15-30% Reduction in overstory tree density	<u>Overstory reduction:</u> After 1 burn (n=17): 5% (± 5) After 2 burns (n=9): 9% (± 11) After 3 burns (n=5): 7% (± 11)	Insufficient data.	2018
	>200 tall (>1m) Oak seedlings /ac	<u>Oak Seedling Density:</u> Preburn density (n=17): 71 (± 66) After 1 burn (n=17): 229/ac (± 180) After 2 burns (n=9): 279/ac (± 152) After 3 burns (n=5): 16 (± 25)	Insufficient data. But trend is positive. High variability.	2018
	>30% Cover by native herbs/subshrubs	Preburn cover (n=9): 4% ($\pm 2\%$) After 1 burn (n=9): 4% ($\pm 2\%$)	Insufficient data.	2011

Kings Mountain National Military Park (KIMO): 2019 Fire Effects Monitoring Annual Report

Activity Summary

The fire ecologist/fire effects team made three trips to KIMO in 2019. The fire effects crew participated in the May prescribed burn of South Brushy, which was the third entry of fire into this unit. Wylie and Allyson attended and presented at a workshop for quail habitat during the summer. Everyone returned in September to conduct year-10 monitoring of the Coneflower and Aster burn units, monitor the effects of the South Brushy burn, and monitor/discuss effects of mechanical treatments in the North-Central project area. A summary of the South Brushy prescribed burn and monitoring can be found in the “Review of 2019 Projects” section below.

Review of 2019 Projects

2019 South Brushy Rx Burn Review:

The South Brushy burn unit is located in the southwest portion of Kings Mountain National Military Park (KIMO) along the southern park boundary and Piedmont Road. The recent May 2, 2019 prescribed burn marks the third treatment of this unit with previous burns occurring in 2005 and 2010. This area is comprised primarily of the southern terminus of the prominent Brushy Ridge that runs southwest to northeast through the national park along with adjacent spur ridges descending from the unit boundaries down to Garner Branch at the tip of Brushy Ridge. The main ridge and upper slopes are rocky with windswept leaf litter and have a canopy largely dominated by chestnut oak (*Quercus montana*) but also commonly include shortleaf pine (*Pinus echinata*), blackjack oak (*Quercus marilandica*), and scarlet oak (*Quercus coccinea*). The understory can be fairly barren but often contains sparse tufts of little bluestem (*Schizachyrium scoparium*), patches of low growing blueberries (*Vaccinium* spp.), scattered tall shrubs such as



Photo 1. Fire backing off the south side of the main ridge during the 2019 prescribed burn

mountain laurel (*Kalmia latifolia*) and sparkleberry (*Vaccinium arboreum*), stunted persimmon trees (*Diospyros virginiana*), and mostly notably numerous shortleaf pine seedlings that have established in canopy gaps created from prior burns. Additionally, the spur ridges and slopes along the unit boundaries tend to be a mix of successional forest with various dry oak species (*Quercus* spp.), Virginia pine (*Pinus virginiana*), and mixed hardwoods.

The recent 2019 burn was perhaps the lightest of the 3 burn treatments with overall severity being very low to low (**Figure 1**). Burn day conditions were humid and given the shading from a canopy in full greenup, overall fire activity was moderated. The main ridge, however, burned well especially along the ridgetop and southern slopes where fire generally consumed the leaf litter and top-killed low-growing blueberry shrubs and hardwood seedlings 3-5' tall, but had little impact on the upper canopy.

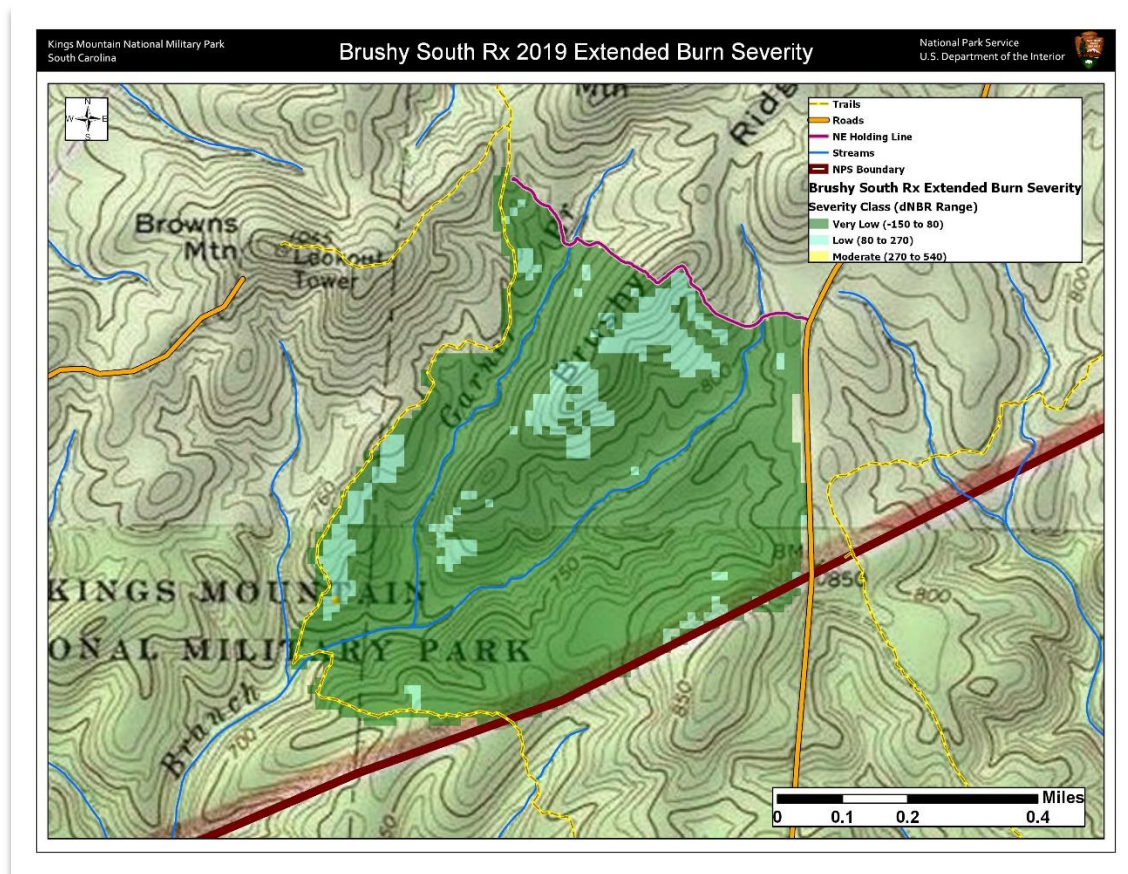


Figure 1. Map showing the extended burn severity for the 2019 prescribed burn of the South Brushy unit. Areas of dark green show very low severity and aqua blue is low severity. Note the much of the low severity is along the main ridge where pervious canopy gaps are present and where the driest fuels are concentrated. The low severity area along the west line represents an area with sparse canopy and mountain laurel that was scorched and/or top-killed.

Interestingly, despite the moderated fire intensity, top-kill of large dense mountain laurel thickets along the main ridge and on an adjacent ridge on the western unit boundary was very consistent (**Photo 2**).



Photo 2. Picture showing typical top-kill of mountain laurel along the main ridge

Top-kill of shortleaf pine seedlings and poles was low while adjacent competing hardwood stems of similar sizes were frequently top-killed, further favoring dominance of the shortleaf stems. Additionally, little bluestem appeared to be responding well to repeated burns, showing an often sparse but consistent expansion, especially in canopy gap areas. With continued burning the main ridge will likely continue to convert into an open shortleaf pine-blackjack oak woodland with a sparse grassy understory dominated by little bluestem (**Photo 3**).



Photo 3. Example of an old canopy gap along the main ridge with scattered shortleaf pine, blackjack oak, and little bluestem. These areas continued to be favored by repeated burns and will likely convert to a shortleaf pine woodland in the long term.

Overall effects along the southern edge of the burn were light with areas of mixed oak and pine receiving a fairly continuous underburn, while more successional forest and protected areas lower on the slopes were patchy or unburned. Given the more disturbed land use history of this area, however, these results are within the overall objects for this unit, which are really more targeted at Brushy Ridge proper.

Key Takeaway Points

- Despite the marginal weather conditions and low intensity fire behavior, the results were positive, with good top-kill of hardwood resprouts and mountain laurel along the main ridge and upper slopes.
- Both shortleaf pine and little bluestem have responded well to repeated burning. Canopy gaps along the main ridgeline are slowly becoming dominated by these species and further burns will likely create an open shortleaf pine woodland in these areas.

Long Term Monitoring Results

No updates have been made to the long term monitoring results for this report. Most of **Table 2** was updated recently, and there was not enough new data collected in 2019 to make a substantial update to these most recent analyses.

Table 2. Objectives and long-term monitoring results for KIMO

Monitoring Type	Management Objective Restoration Phase- (After 4 burns)	Monitoring Results (80% confidence intervals)	Objective Achieved?	Year Last Analysis Completed
Dry Oak Forest (FQUM01) <i>21 plots:</i> <i>20 have burned once</i> <i>19 have burned twice</i> <i>17 have burned 3 times</i> <i>9 have burned 4 times</i>	>50% Reduction in total fuel loading	Total fuel reduction: After 1 burn (n=19): 40% ($\pm 6\%$) After 2 burns (n=18): 46% ($\pm 5\%$) After 3 burns (n=17): 57% ($\pm 5\%$) After 4 burns (n=7): 61% ($\pm 6\%$)	Trends suggest that the objective is being accomplished after 3 burns	2018
	>70% Reduction in pole-sized tree density	Pole reduction: After 1 burn (n=20): 42% (± 9) After 2 burns (n=17): 58% (± 8) After 3 burns (n=15): 71% (± 7) After 4 burns (n=5): 76% (± 12)	Insufficient data. But trend is positive.	2018
	15-30% Reduction in overstory tree density	Overstory reduction: After 1 burn (n=20): 7% (± 4) After 2 burns (n=17): 11% (± 5) After 3 burns (n=17): 21% (± 7) After 4 burns (n=6): 26% (± 16)	Insufficient data. But trend is positive.	2018
	>200 tall (>1m) Oak seedlings/acre	Oak Seedling Density (stems/acre): Preburn density (n=15): 183 (± 132) After 1 burn (n=20): 77/ac (± 47) After 2 burns (n=17): 233/ac (± 171) After 3 burns (n=16): 182 (± 137)	Insufficient data. High variability. Objective needs to be revised to include shortleaf pine seedlings.	2018
	>15% Cover by native herbs/subshrubs	Preburn cover (n=19): <1% After 1 burn (n=19): 1% After 2 burns (n=19): 1-2%	No, but more burns are needed.	2009
Chestnut Oak-Blackjack Oak Woodland (FQUMA1) <i>8 plots</i>	>50% Reduction in total fuel loading	Total fuel reduction: After 1 burn (n=7): 47% ($\pm 4\%$)	Insufficient data.	2009
	>70% Reduction in pole-sized tree density	Pole reduction: After 1 burn (n=8): 45% ($\pm 12\%$) After 2 burns (n=4): 62% ($\pm 12\%$)	Insufficient data.	2009
	15-30% Reduction in overstory tree density	Overstory reduction: After 1 burn (n=8): 30% ($\pm 11\%$)	Insufficient data.	2009
	>30% Cover by native herbs	Preburn cover (n=7): 6% Cover after 1 burn (n=7): 9%	Insufficient data.	2009

Moore's Creek National Battlefield (MOCR): 2019 Fire Effects Monitoring Annual Report

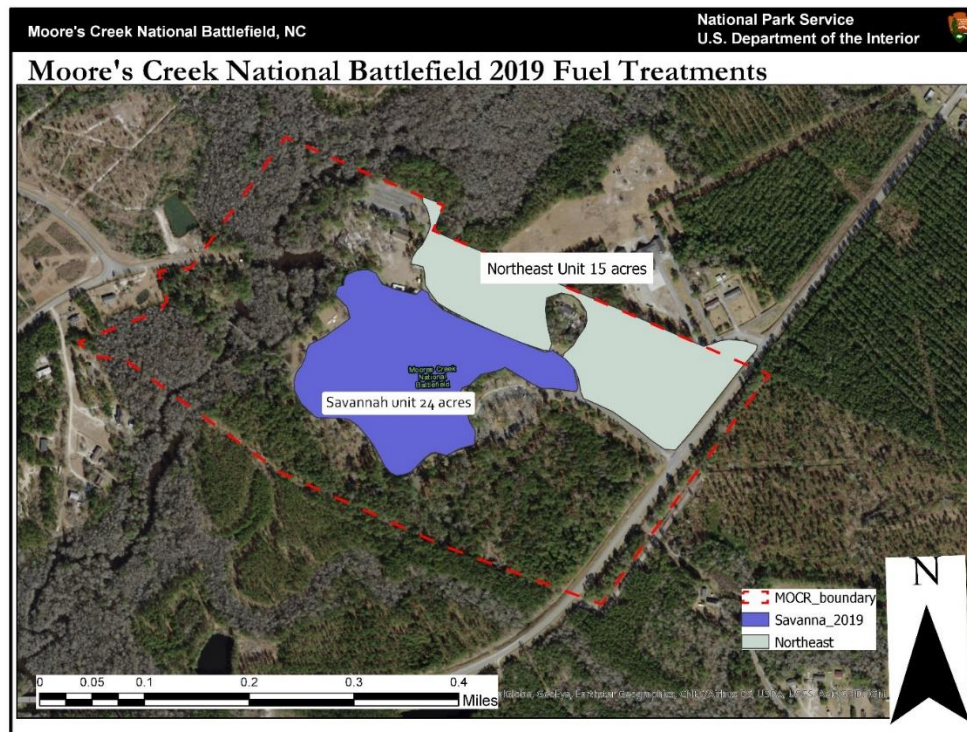
Activity Summary

The fire effects crew was not able to make a visit to MOCR during 2019. A trip to monitor the most recent burns and the overall prescribed fire program in September had to be cancelled due to Hurricane Dorian.

Review of 2019 Projects

Savannah and Northeast Prescribed Burns:

No FEMO report was filed for either project and no monitoring was completed for FY19 Rx burns. The following map was submitted into the NPS national treatment database.



May 2019

Table 1: From 1989 to 1995, burns were conducted by the State. Beginning in 2010 to present, burns are conducted by the NPS.

Date	Unit(s)	Acreage
March 8, 1989	Savannah	3
March 19, 1990	Savannah	5
April 9, 1991	Savannah	3
March 9, 1992	Savannah	3
March 1, 1993	South and Savannah	5
February 24, 1995	Wildfire	0.1
March 17, 2010	Savannah	4.5
February 10, 2012	Savannah	12
April 22, 2014	Savannah, South and West	24
April 21, 2016	Savannah, South and West	37
April 11, 2017	Savannah, North and East	42
March 29, 2018	Savannah and Southwest	37
April 11, 2019	Savannah and Northeast	24, 30

Additional Program Information

Table 1. Planning - 2019

Park	Does Park have written DFCs? (yes or no)	Date Park-level Monitoring Plan completed (or revised)	Total # of Project- or Community-level Monitoring Plans (not just 2019)	Assisted with how many BAER plans in 2019?
BISO	yes	n/a	0	0
BLRI	yes	n/a	0	0
CAHA	no	n/a	0	0
CHCH	yes	n/a	0	0
CONG	yes	n/a	0	0
COWP	no	n/a	0	0
CUGA	yes	n/a	0	0
GRSM	yes	n/a	0	0
KIMO	yes	n/a	0	0
MOCR	no	n/a	0	0

Table 2. Monitoring - 2019

Park	% 2019 Data entered	%2019 Data Quality Checked	# of Prescribed Fires Monitored	# Non-Fire Fuels Treatments Monitored	#Wildfires Monitored	#BAER Treatments Monitored
BISO	100	100	3	0	0	0
BLRI	n/a	n/a	1	0	0	0
CAHA	n/a	n/a	0	4	0	0
CHCH	100	100	0	0	0	0
CONG	100	100	3	3	0	0
COWP	n/a	n/a	0	0	0	0
CUGA	100	100	1	0	0	0
GRSM	100	100	5	2	3	0
KIMO	100	100	5	1	0	0
MOCR	n/a	n/a	0	0	0	0

Table 3. Communicating Results - 2019

Park	# of Project Monitoring Reports completed in 2019	# of Annual meeting(s) with Park staff	# of Formal presentations of results	Do you use Minitab?*
BISO	3	0	0	Yes
BLRI	1	1	0	Yes
CAHA	3	0	0	Yes
CHCH	0	1	0	Yes
CONG	2	1	0	Yes
COWP	0	0	0	No
CUGA	1	0	0	Yes
GRSM	5	1	2	Yes
KIMO	1	1	1	Yes
MOCR	0	0	0	No

Table 4. Research - 2019

Park	Are research needs identified in FMP or Monitoring Plan? (yes or no)	# of Proposals Submitted in 2019	# of Proposals Funded in 2019	# of Research Projects Supported in 2019*	Additional Comments
BISO	yes	0	0	1	
BLRI	yes	0	0	0	
CONG	yes	0	0	0	
COWP	yes	0	0	0	
CUGA	yes	0	0	0	
GRSM	yes	2	2	3	
KIMO	yes	0	0	0	
MOCR	yes	0	0	0	

*Number of funded research projects, new or ongoing, supported by the fire ecology program including logistical info or support, staffing, etc.

Fire Ecologist and Fire Effects Crew Accomplishments and Areas of Focus

Table 1. Fire Ecologist 2019 Accomplishments/Focus Areas

Category	Percent Time	Accomplishments and/or areas of activities
Data Collection	15%	Field work at GRSM, KIMO, CHCH, CUGA, BISO. FMH plots, LFEM plots, Photo-monitoring, and qualitative surveys.
Planning	15%	Fire effects program planning. APC Zone planning (senior staff discussions) . Fuels program planning meetings at CHCH, GRSM.
Data analysis	5%	Work completed on 2018 and 2019 Annual Reports.
Data management	10%	Routine data management tasks. Fire records. GIS data.
Supervision/Admin	20%	Supervision, Performance evaluations, Training, IDPs, travel, payroll, crew support, purchasing etc.
Fire Operations	1%	Limited support.
Writing	5%	Proposal writing. Annual report. Detailed correspondence.
Educational Outreach	5%	Presentations to NPS I&M Program, Experience your Smokies
Partnerships	9%	New partnerships with NPS I&M: SECN and CUPN, Continued communications with numerous partners. TNC, FLN, CAFMS.
Research/ Publications	10%	Contributed to proposals, reviewed proposals, shepherded agreements, met with multiple researchers to share information, heavy support for Virginia Tech field research at GRSM
Miscellaneous	3%	Mostly communication; E-mails, phone calls, informal planning discussions.
Training	2%	Supervisory and required NPS training; fire refresher; ArcPro

Table 2. Fire Effects Crew 2019 Accomplishments/Focus Areas

Category	Percent Time	Notes
Planning	10%	Planning related to prescribed fire projects including meetings, preparation for burns and communications of objectives
FMH plots	30%	FMH plots at CONG, GRSM, KIMO and BISO, CUGA
Qualitative Monitoring	4%	Completed Qualitative monitoring at BISO, KIMO, GRSM, CUGA
CBI plots/Landscape Fire Effects Monitoring (LFEM)	5%	Long term LFEM plots at GRSM @ Short Bunk (permanent plots) New program at CHCH based on LFEM methods
Wildfire/All-Hazard assignments	5%	Paxton and Arulanantham – READs for Hurricane Dorian response; All – WF at GRSM
Prescribed fire projects	10%	Assisted with implementation and mop-up of burns at CUGA, KIMO, and GRSM; Paxton assisted TNC
Non-fire fuels projects	5%	Photo document Ski Mountain Fuels Reduction Project (1 mile section); Harry Hampton Mastication; Cades Cove mastication
Data entry	10%	100% entered with thanks to crewmember Allyson Arulanantham
Data analysis	<5%	This is expected to be very low number or zero for fire effects crew/lead monitor
Supervision/Admin	10%	Supervision of crew for completing field and office work, as well as time, travel credit card and purchasing paperwork. Other Administrative duties accomplished were submitting CY2019 fire polygons to Regional Fire GIS coordinator. Quality Checking AP Zone Fire Occurrence Data
Training	5%	Basic NPS stuff; Refresher; Entire crew helped teach multiple refreshers at multiple parks; Entire crew helped teach 130/190 at GRSM; ArcPro.
Miscellaneous	<1	Transition to ArcPro GIS



The End.

