National Park Service
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Natural Resource Program Center

Forest Community Monitoring Baseline Report, Hot Springs National Park

Natural Resource Technical Report NPS/HTLN/NRTR—2008/081

ON THE COVER
Oak-hickory-pine forest of Hot Springs National Park
HTLN staff photograph

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Natural Resource Technical Report NPS/HTLN/NRTR—2008/081

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Table of Contents

Figures

Page

Tables

Page

Executive Summary

The mountain lands of Hot Springs National Park (HOSP) are part of the Ouachita Mountains. The forest is in the transitional zone between the Ozark Plateau and the Gulf Coastal Plain, thus having an overstory of oak-hickory-pine and sparsely vegetated understory beneath the mostly closed canopy. Shortleaf pine is present throughout the mountain lands and acts as a backdrop for the different oak and hickory species that define the regional forest.

Understanding the mountain lands forested composition and structure is beneficial for decision making regarding the future management of the natural resources on and in the vicinity of Sugarloaf Mountain. This area, part of the recharge zone for the hot springs, has not been actively managed for forest patterns or processes. The area has not been immediately impacted or threatened by non-natural disturbances outside of fire suppression efforts in the past few decades. The park and its natural resources have been heavily impacted by human use between 1832 and 1916 insofar as “nearly all of the lands…have either been farmed, mined for gravel, logged for pulpwood, or cleared for homesites.” (NPS, 1986).

The Heartland Inventory and Monitoring Network and Prairie Cluster Prototype Monitoring Program (HTLN) implemented monitoring at HOSP in 2007 to provide an analysis of baseline conditions that can be used to assess future change in forest communities. Seven forested sites were sampled in mid-June of 2007, to obtain cover estimates and species identification of the overstory canopy, understory shrub, and herbaceous layer.

Shortleaf pine was present at six of the seven sites. An overstory dominated by oak and hickory species with a shortleaf pine component is mirrored in the regeneration layer. The establishment of persimmon and sassafras indicate a change in the fire regime for the area allowing the growth of more shade tolerant tree species.

The oak-hickory-pine forests of the Sugarloaf Mountain area at HOSP are indicative of forested areas across the Ouachita Mountains in Arkansas. Overstory composition and structure reflect a forest affected by changes in the natural disturbance regime as well as a history of anthropogenic disturbances (e.g., logging). A combination of natural fires along with topo-edaphic features traditionally maintained the forest in a late seral stage, dominated by shortleaf pine and a mix of xeric and mesic oak species distributed according to slope position, aspect, exposure, and soil depth.

Natural pathways for succession currently are in place across the Sugarloaf Mountain area. Areas currently dominated by xeric oak species or mesic oak and hickory species in the overstory will tend to persist under current management. While nearly all areas have shortleaf pine, the abundance, size, and recruitment of this species is dependent on topo-edaphic features that promote the growth of certain oak and hickory species at a local scale. While increased prescribed fire or reduced fire suppression may benefit shortleaf pine, an alternate goal of a functioning oak-hickory-pine forest may be more beneficial from both a management and natural resource standpoint.

Introduction

The natural resources of Hot Springs National Park are squarely focused on its namesake, the thermal hot springs and their recharge zone. The mountain lands surrounding the historic bathhouse row of the park have "historically been managed to present a scenic backdrop…and to provide opportunities for outdoor relaxation and exercise associated with the 'cure'" (NPS, 1986). Visitors have been attracted to the area in general and specifically the hot springs of bathhouse row since before the park's inception. For most, the surrounding mountains were scenery which would aid in enjoying the more immediate benefits of the thermal springs.

The mountain lands are most important as part of the recharge zone for the hot springs. Therefore the underlying geology and soil, not the emergent natural communities, are of primary importance. This is reflected in the General Management Plan (NPS, 1986): "Better examples of the region's natural resources are available in nearby national forests and state parks." A single exception to this statement is the 150-acre stand of shortleaf pine on the north slope of Sugarloaf Mountain that comprises the protected natural area subzone of the park.

The mountain lands of the park are part of the Ouachita Mountains. The forest of the park is in the transitional zone between the Ozark Plateau and the Gulf Coastal Plain, thus having an overstory of oak-hickory-pine (*Quercus-Carya-Pinus*) and sparsely vegetated understory beneath the mostly closed canopy. Shortleaf pine (*Pinus echinata*) is present throughout the mountain lands and acts as a backdrop for the different oak and hickory species that define the regional forest.

Understanding the mountain lands forested composition and structure is beneficial for decision making regarding the future management of the natural resources on and in the vicinity of Sugarloaf Mountain. This area, part of the recharge zone for the hot springs, has not been actively managed for forest patterns or processes. The area has not been immediately impacted or threatened by non-natural disturbances outside of fire suppression efforts in the past few decades. The park and its natural resources have been heavily impacted by human use between 1832 and 1916 insofar as "nearly all of the lands…have either been farmed, mined for gravel, logged for pulpwood, or cleared for homesites." (NPS, 1986). It is with this understanding that vegetation monitoring was undertaken in a portion of the mountain lands of Hot Springs National Park.

Methods

Field methods

The Heartland Inventory and Monitoring Network and Prairie Cluster Prototype Monitoring Program (HTLN) implemented monitoring at HOSP in 2007 to provide an analysis of baseline conditions that can be used to assess future change in forest communities (see DeBacker *et al.* 2004 for detailed information on the monitoring protocol). Seven forested sites (consisting of ten $10m^2$ plots at each site) were sampled in mid-June of 2007, to obtain accurate cover estimates and identification of the overstory canopy, understory shrub, and herbaceous layer (Fig. 1). Sites

were established according to the protocols in DeBacker *et al.* 2004. Pre-stratification of sites was based on slope position (elevation range and aspect). These strata were used to delineate oak-hickory-pine forest types by Dale and Watts (1980).

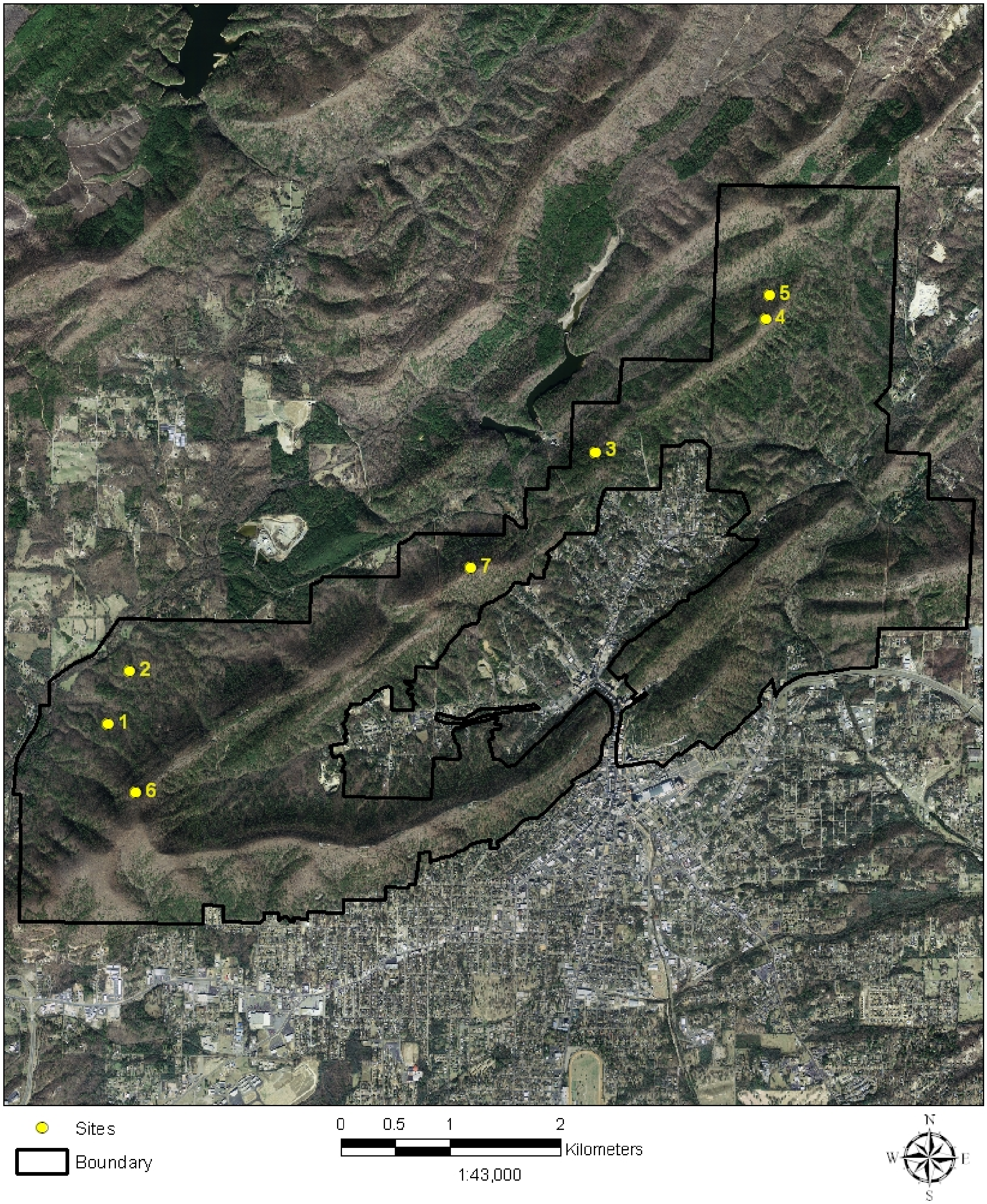

Figure 1. Map of Hot Springs National Park displaying vegetation monitoring sites.

Fire effects monitoring plots in the North Mountain burn unit were sampled in 2006 immediately following a prescribed fire. In 2007, fire effects monitoring plots in the Sugarloaf Mountain burn unit were sampled immediately following a prescribed fire. These sites were sampled to monitor the effects of a prescribed burn on overstory density along with understory cover and diversity. No HTLN sites were affected by either burn.

The HTLN sampling design, based on the design of the Konza Prairie Long-Term Ecological Research Program, consists of randomly located, permanent, paired transects 50 meters in length and 20 meters apart with five circular $10m^2$ plots systematically spaced along each transect (Fig. 2).

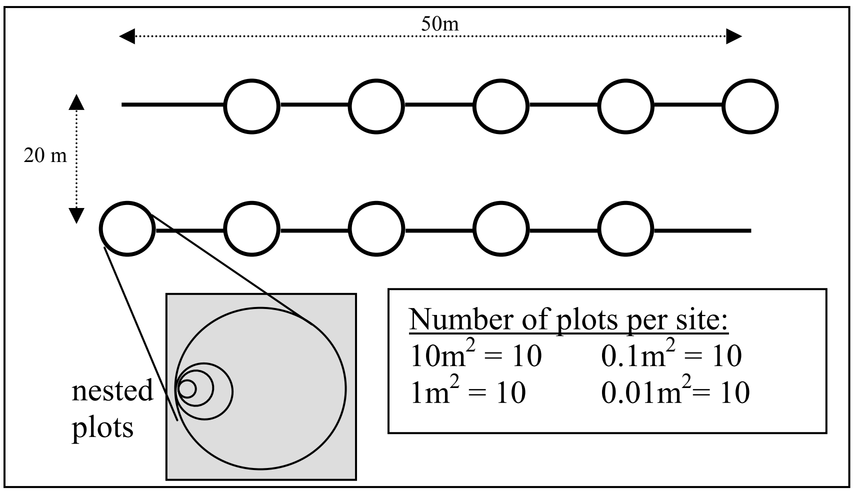

Figure 2. HTLN vegetation community sample design showing transects and plots including nested plots.

The primary sample unit is the site and circular plots along each transect are secondary sample units. Each $10m^2$ plot also includes nested subplots of $1m^2$, $0.1m^2$, and $0.01m^2$ for frequency estimates at multiple scales. For this report, both understory frequency and cover estimates are reported from the $10m^2$ plots. Working systematically from the smallest subplot ($0.01m^2$) to the largest ($10m^2$), all species are identified and foliar cover is estimated. Forest understory vegetation is sampled in this manner. For forested communities, overstory canopy cover and regeneration species composition and structure data are collected at secondary sample units (plot level). Overstory tree (stems ≥ 5.0 cm diameter at breast height, dbh) size (dbh) and condition data are collected for each species within the 0.1ha area in the 20x50m area formed between the two transects. This 0.1ha area is the primary sample site for overstory tree composition, density, and basal area measurements.

Analytical methods

For analyses, the site is used as the unit of replication and secondary sample units are pooled or averaged. Once estimates for all parameters have been obtained for each sample unit, averages

with a measure of variability (standard deviation) among sample sites are obtained.

Individual species abundances

Individual species frequency and percent foliar cover are calculated for each site. Frequency is defined as the number of times a species is present in a given number of plots of a particular size (Raunkiaer 1934). With the primary sample unit (site) as the replicate, species frequency is reported as the proportion (or percentage) of plots in which the species occurs within each site.

Foliar cover serves as an estimate of abundance for herbaceous species. The cover class intervals are converted to median values to estimate percent cover for each herbaceous and shrub species (Table 1). Mean percent cover is then calculated as the species percent cover for a sampling unit, averaged for all plots in which the species occurs (i.e., plots within a site with zero values for a species are excluded).

Table 1. Modified Daubenmire cover value scale used to determine herbaceous/shrub species cover for the HTLN Parks.

Cover Class Codes	Range of Cover (%)	Class Midpoints (%)
7	95-100	97.5
6	75-95	85.0
5	50-75	62.5
4	25-50	37.5
3	5-25	15.0
2	1-5	2.5
1	0-0.99	0.5

Understory species are grouped into two cover types according to Ozark Highlands Fire Effects Monitoring Module. All non-woody species are considered part of the herbaceous cover type while woody species (primarily shrub species) constitute the woody species cover type.

Plant species richness, diversity, and evenness

Plant diversity for each site is calculated using the **Shannon diversity index**:

$$H' = -\sum_{i=1}^{n} p_i \ln p_i$$

where p*i* is the relative cover of species *i* (Shannon 1948).

Species distribution **evenness** is calculated by site using Pielou (J):

$$J' = H' / H_{max},$$

where H' is the Shannon diversity index and H_{max} is the maximum possible diversity for a given number of species if all species are present in equal numbers ((ln(species richness)). J' is a measure of distribution of species within a community as compared to equal distribution and maximum diversity (Pielou 1969).

Species richness (S) is determined as the total number of plant taxa recorded per site. Species richness is calculated with all species (native and exotic) included in the estimate.

Simpson's index of diversity for an infinite population (D) is calculated by site. It is the likelihood that two randomly chosen individuals from a site will be different species and emphasizes common species (McCune and Grace 2002). It is calculated by site using the complement of Simpson's original index of dominance:

$$\text{Simpson's diversity index} = 1 - \sum_{i}^{n} p_i^2$$

Shannon and Simpson's diversity index values are converted into effective number of species for the understory vegetation (H_e and D_e, respectively). This allowed for both diversity measures to be compared directly to species richness of the sites (S) and across the natural area (Joust 2006). Shannon diversity index was converted into effective number of species (Shannon number, H_e) using the following formula:

$$H_e = \exp^{(H)}$$

where H is the Shannon diversity index value. Effective number of species based on Simpson's diversity index (Simpson's number, D_e) is the inverse of the index value or:

$$D_e = 1/(1-D)$$

where D is the Simpson's diversity index value.

When interested in measuring diversity in a single community it is best to use all three diversity measures to most accurately reflect diversity (Joust 2006). At the most basic level of species diversity, species richness provides a total number of distinct species sampled per unit area. Richness is insensitive to species abundance. Therefore a single individual species occurring only once in a community is treated the same as a species with thousands of individuals in the community. This measure is an indicator of species diversity but does not provide any information about the composition of species within the community. Shannon diversity index weights species by their abundance. It is an intermediate between species richness and Simpson's diversity index in its sensitivity to rare species. Therefore this diversity measure provides information on both the count of unique species and their abundance or density in the community. Simpson's diversity index goes one step further by disproportionately favoring dominant species based on species abundance and is little affected by gain or loss of rare species.

Dominance takes into account the species abundance and evenness of species distribution in the community. The degree of species dominance in the community is reflected by the degree to which $S > H_e > D_e$ when evenness (E) remains constant in a single community. The difference in number of species between the diversity measures reflects both how each metric considers uncommon species and how species diversity is partitioned within the community. If all species occurred in equal abundance in the community, then $S = H_e = D_e$. Effective number of species for each diversity measure reflects the number of species found in a similar community when all species occur in equal density. For example, if S = 100 and D_e is equal to 20, than the community is dominated by 20 species and 80 species occur in low abundance. Such a

community would be equivalent to a community with just 20 species all occurring in equal abundance.

Overstory and understory data summary

In the forest community, summary statistics for overstory and understory (stems ≥ 5.0 cm dbh) tree species are calculated. For each species, density and basal area are calculated. Density, or the number of stems per sample unit (scaled to hectare), is a measure of abundance for tree species. Overstory/understory density is calculated for five size classes (Table 2).

Table 2. Diameter at breast height (cm) size class ranges for overstory trees.

Size Class	dbh (cm)
1	5 - 14.9
2	15 - 24.9
3	25 - 34.9
4	35 - 44.9
5	45+

Basal area (m^2) is calculated using the standard formula: $dbh^2 \times 0.00007854$. Data are scaled to hectare, and summarized for the community and forest types using site data.

Seedling and sapling data summary

In the forested natural area, summary statistics for seedlings and sapling (stems < 5.0 cm dbh) tree species are calculated. Tree seedling/sapling density is reported in three size classes (cm dbh):

- seedlings (stems < 0.5 m in height)
- small saplings (stems ≥ 0.5 m in height but < 2.5 cm dbh)
- large saplings (stems ≥ 2.5 cm dbh but < 5.0 cm dbh)

When only a single small or large sapling was detected, regeneration data were summarized for all three size classes.

Results

The seven vegetation monitoring sites were established to represent three different elevation ranges and two aspects. However sites could not be post-stratified into forest types according to their location features or overstory composition and structure. Therefore results are summarized for all sites along with site averages.

Forest understory

A total of 62 non-tree understory species were sampled among the seven HTLN monitoring sites. The average number of species sampled per site (S) was 23.4 ± 4 species (mean ± 1 standard

deviation). It is important to remember that species richness (S) is a function of sample area, so that as the total sample area increases, so does the overall species richness. The effective number of species per site as measured by Shannon number (H_e) was nearly 50% of the total richness accumulated over all sites (Fig 3). Furthermore, evenness (J') for all sites and individual sites was 0.82, indicating that the species sampled in the understory were distributed evenly within and among sites. On average a site contained 3.7 ± 1.9 unique species (detected only in a single site); thus sites shared about 94% of the same understory species. Species diversity in the forest understory was partitioned within sites rather than among sites. This indicates that across the Sugarloaf Mountain area, understory species found in one HTLN monitoring site will be similar to all six other monitoring sites, regardless of overstory composition, aspect or elevation.

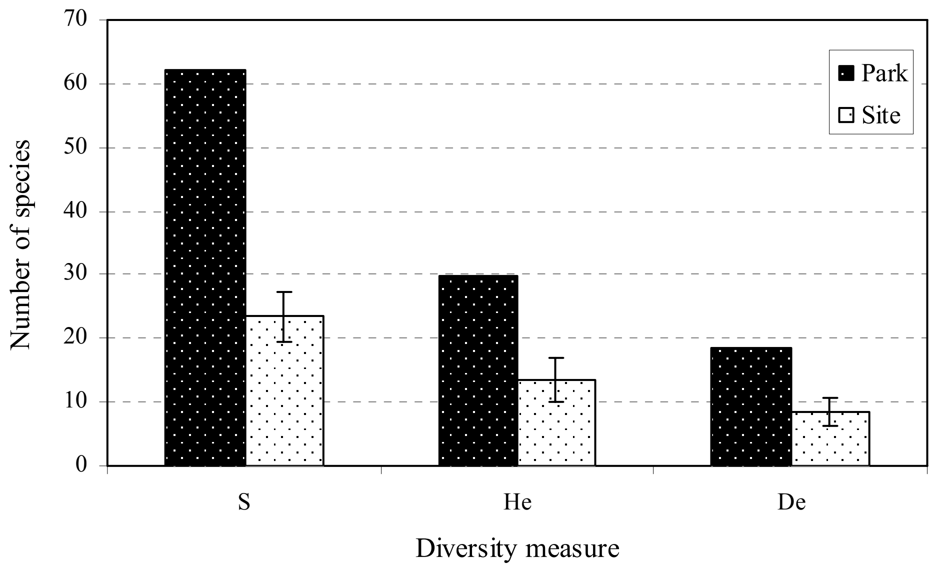

Figure 3. Comparison of understory species diversity for all sites (Park, n=7) and individual site mean (± 1 standard deviation). Species diversity measures: richness (S), Shannon number (H_e) and Simpson's number (D_e).

Approximately one-third of species within all sites were considered dominant species as indicated by D_e (18.6 and 8.4 ± 2 for all sites and individual site, respectively). Dominance was measured by species frequency within and among sites. Even though there were a large number of dominant species shared among sites, species occurred in low abundance as estimated by foliar cover (Appendix A). Only ten species were sampled with a foliar cover estimate greater than 2%.

Understory species were grouped into understory cover type groups to compare herbaceous and woody species foliar cover. Cover type delineation was based on Ozark Highlands Fire Effects Monitoring Module groups. Foliar cover for both cover type groups was low among all sites. Mean herbaceous foliar cover was 1.0 % (± 2.2) while woody species cover was noticeably higher (6.1 ± 9.7%) across all sites.

This paucity in understory foliar cover is balanced by the ground cover estimates for each site. Ground cover within sites was predominantly woody debris and leaf litter (Table 3). The forested understory was composed of sparse vegetative cover dominated by non-vegetative ground cover.

Table 3. Ground cover estimates (%) for five ground cover classes estimated for each site and averaged for all sites (± 1 standard deviation).

Site	Bare Soil	Rock	Grass Litter	Woody Debris	Leaf Litter
HOSP_1	0.5	1.9	0.5	6.4	82.8
HOSP_2	0	3.0	0.9	5.2	81.8
HOSP_3	1.3	1.9	0.5	11.4	76.0
HOSP_4	0.5	5.9	0.5	16.1	82.8
HOSP_5	0	0.5	0	7.8	85.0
HOSP_6	0.5	9.2	0	15.9	73.5
HOSP_7	0.5	5.1	0	13.5	82.8
All Sites	0.7 (0.4)	3.9 (3.0)	0.6 (0.2)	10.9 (4.5)	80.6 (4.2)

High leaf litter cover estimates and moderate woody debris estimates may have implications on both fuel loading and overstory tree regeneration. A high percentage of cover for these two groups also has a limiting affect on total foliar cover of the herbaceous understory.

Exotic invasive species were detected in low abundance across the monitoring sites. Only two species were detected (*Lactuca serriola* and *Lonicera* spp.; Appendix A). Both occurred at a frequency of 1.4% and foliar cover estimate of 0.5%. Therefore, exotic invasive species were not a dominant component of the understory at the Sugarloaf Mountain monitoring sites.

Forest overstory

Overall the Sugarloaf Mountain area sites represent a transitional forest between the shortleaf pine cover type and a climax type of upland oaks. This successional stage is characterized by uneven age stands composed primarily of dry upland oaks (post, red and blackjack oaks), mesic white oak and shortleaf pine. As size class increased the number of distinct tree species within size class decreased (Twelve taxa in size class 1 to four taxa in size class 5; Table 4). Oak species tended to have the highest mean density across all size classes along with black hickory and shortleaf pine. Shortleaf pine, white oak and post oak had the highest mean basal area in the two largest size classes (size class 4, 5; Table 4). Multiple canopy layers were present in all stands as indicated by the mean density of species among all size classes.

Table 4. Mean (± 1 standard deviation) overstory tree density (trees/ha) and basal area (m^2/ha), by species size class among all sites (n=7).

SizeClass	Scientific Name	Common Name	Density	Basal Area
1	*Carya alba*	mockernut hickory	13.3 (5.8)	0.09 (0.07)
1	*Carya cordiformis*	bitternut hickory	20	0.23
1	*Carya texana*	black hickory	57.5 (69.5)	0.51 (0.63)
1	*Cornus florida*	flowering dogwood	10	0.04
1	*Nyssa sylvatica*	blackgum	45.0 (7.1)	0.17 (0.02)
1	*Pinus echinata*	shortleaf pine	10	0.17
1	*Prunus serotina*	black cherry	20.0 (8.2)	0.14 (0.04)
1	*Quercus alba*	white oak	30.0 (14.1)	0.26 (0.10)
1	*Quercus marilandica*	blackjack oak	20	0.23
1	*Quercus rubra*	red oak	16.7 (11.5)	0.20 (0.14)
1	*Quercus stellata*	post oak	15.0 (7.1)	0.09 (0.06)
1	snag	snag	12.5 (5.0)	0.09 (0.06)
1	*Ulmus alata*	winged elm	60	0.37
2	*Carya alba*	mockernut hickory	23.3 (15.3)	0.69 (0.49)
2	*Carya texana*	black hickory	66.0 (91.8)	2.04 (2.51)
2	*Nyssa sylvatica*	blackgum	10	0.47
2	*Pinus echinata*	shortleaf pine	32.5 (26.3)	1.06 (0.78)
2	*Prunus serotina*	black cherry	30.0 (17.3)	0.82 (0.27)
2	*Quercus alba*	white oak	68.0 (66.9)	2.01 (2.07)
2	*Quercus marilandica*	blackjack oak	20	0.66
2	*Quercus rubra*	red oak	40	0.98
2	*Quercus shumardii*	Shumard's oak	10	0.24
2	*Quercus stellata*	post oak	52.5 (27.5)	1.48 (0.57)
2	snag	snag	14.0 (5.5)	0.45 (0.20)
2	*Ulmus alata*	winged elm	15.0 (7.1)	0.31 (0.14)
3	*Carya alba*	mockernut hickory	16.7 (5.8)	1.01 (0.34)
3	*Carya texana*	black hickory	10	0.67 (0.21)
3	*Pinus echinata*	shortleaf pine	50.0 (60.6)	3.55 (4.13)
3	*Prunus serotina*	black cherry	30	2.43
3	*Quercus alba*	white oak	30.0 (34.6)	2.16 (2.35)
3	*Quercus rubra*	red oak	10	0.73 (0.16)
3	*Quercus stellata*	post oak	30.0 (16.3)	2.34 (1.01)
3	snag	snag	20	1.48
4	*Carya texana*	black hickory	20	2.11
4	*Pinus echinata*	shortleaf pine	20.0 (17.3)	2.47 (2.24)
4	*Quercus alba*	white oak	70	9.07
4	*Quercus rubra*	red oak	15.0 (7.1)	1.71 (0.75)
4	*Quercus* spp.	oak spp.	10	1.07
4	*Quercus stellata*	post oak	20.0 (17.3)	2.22 (1.88)
4	snag	snag	25.0 (7.1)	2.86 (0.97)
5	*Pinus echinata*	shortleaf pine	10	1.69
5	*Quercus alba*	white oak	30.0 (14.1)	5.47 (2.83)
5	*Quercus rubra*	red oak	10	1.89
5	*Quercus stellata*	post oak	10	2.46

Across all sites, 12.5% of the total basal area was found in size class 5, while 82.5% of the total basal area was distributed evenly among size class 2, 3 and 4. Shortleaf pine accounted for 20.8% of the total basal area across all sites with individuals in all size classes. The oak species accounted for 55.5% of the total basal area across all sites with all size classes represented.

Canopy cover was similar among sites (Table 5). Canopy cover for all sites was above 86% in mid-June. There was no discernable difference in canopy cover among sites. Total canopy cover within sites reflected the similarity in overstory structure among sites.

Table 5. Mean percent canopy cover (1 ± standard deviation) of the overstory for each forest site and all sites recorded during June 2007.

Site	Canopy Cover
HOSP_1	92.3 (1.5)
HOSP_2	90.2 (2.8)
HOSP_3	87.5 (5.2)
HOSP_4	86.2 (3.0)
HOSP_5	92.8 (1.8)
HOSP_6	91.3 (3.7)
HOSP_7	91.0 (3.6)
All sites	90.2 (3.1)

The distribution of density and basal area among size classes of overstory trees is common to a seral stage of an oak-hickory forest with a shortleaf pine component. All sites display a dominant overstory and sub-canopy layer as well as dense small tree size layer (size class ≤3) with a closed canopy. All overstory canopy layers are composed primarily of oak species along with shortleaf pine and hickory across the Sugarloaf Mountain area.

Of the fourteen tree species sampled, six were oak species (Table 6). White oak and shortleaf pine had the two highest mean basal areas for all seven sites (2.5 and 2.18 m^2/ha, respectively), however neither had the largest mean density (Table 6). This difference among species in terms of density and basal area reflects the predominance of different species in different size classes, with those species with larger basal area having the majority of their individuals in larger size classes and making up most of the canopy.

Table 6. Mean (± 1 standard deviation) overstory tree density (trees/ha) and basal area (m^2/ha) by species for all sites (n=7).

Scientific Name	Common Name	Density	Basal Area
Carya alba	mockernut hickory	17.8 (9.7)	0.60 (0.50)
Carya cordiformis	bitternut hickory	20	0.23
Carya texana	black hickory	50.0 (69.9)	1.31 (1.73)
Cornus florida	flowering dogwood	10	0.04
Nyssa sylvatica	blackgum	33.3 (20.8)	0.27 (0.18)
Pinus echinata	shortleaf pine	30.0 (35.1)	2.18 (2.54)
Prunus serotina	black cherry	25.0 (12.0)	0.68 (0.80)
Quercus alba	white oak	45.3 (43.4)	2.50 (2.91)
Quercus marilandica	blackjack oak	20	0.44 (0.30)
Quercus rubra	red oak	16.0 (10.7)	0.91 (0.71)
Quercus shumardii	Shumard's oak	10.0 (0.00)	0.62 (0.54)
Quercus spp.	oak spp.	10	1.07
Quercus stellata	post oak	30.7 (23.0)	1.76 (1.22)
snag	snag	15.8 (6.7)	0.82 (1.07)
Ulmus alata	winged elm	30.0 (26.5)	0.33 (0.10)

The structure of the forest on Sugarloaf Mountain is composed primarily of smaller size class trees (< size class 4) as indicated by mean number of trees sampled within each site (Fig. 4). Mean basal area within sites is distributed evenly among the middle three size classes. Taken together, the closed canopy and size class distribution within and among sites reflects a forest that has been impacted by stand altering disturbances in the past with a few larger trees able to persist.

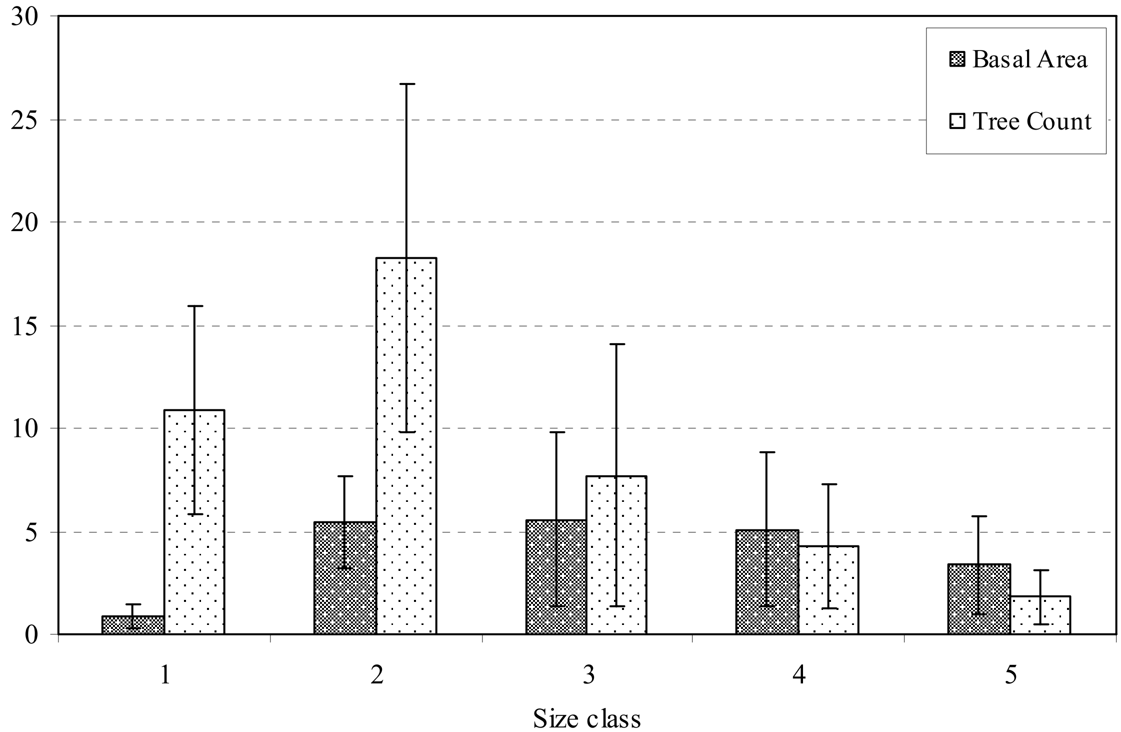

Figure 4. Mean (± 1 standard deviation) site overstory basal area (m^2/ha) and tree count by size class.

The regeneration layer of the overstory was dominated by the seedling size class (696 seedlings among all sites compared to 141 and 39 small and large saplings, respectively). In the regeneration layer, there were five additional species to the fourteen tree species in the overstory: red maple, eastern red cedar, hophornbeam, black locust, and sassafras. All were present in low densities across all three regeneration size classes (Table 7). Most notable in the regeneration layer was the presence of small and large saplings.

Table 7. Mean (± 1 standard deviation) tree regeneration density (trees/ha) for all sites (n-=7).

Scientific Name	Common Name	Seedling Density	Small Sapling Density	Large Sapling Density
Acer rubrum	red maple	300.0 (519.6)	100.0 (100.0)	0
Amelanchier arborea	serviceberry	333.3 (152.8)	166.7 (152.8)	33.3 (57.7)
Carya alba	mockernut hickory	66.7 (57.7)	100.0 (100.0)	33.3 (57.7)
Carya spp.	hickory spp.	2428.6 (2180.8)	42.9 (113.4)	0
Carya texana	black hickory	60.0 (134.2)	800.0 (809.3)	400.0 (561.2)
Cornus florida	flowering dogwood	475.0 (419.3)	200.0 (244.9)	0
Crataegus spp.	hawthorn	133.3 (57.7)	33.3 (57.7)	66.7 (115.5)
Diospyros virginiana	persimmon	200.0 (141.4)	150.0 (212.1)	0
Frangula caroliniana	Carolina buckthorn	166.7 (115.5)	33.3 (57.7)	166.7 (288.7)
Juniperus virginiana	eastern red cedar	100.0	0	0
Nyssa sylvatica	blackgum	766.7 (907.4)	566.7 (737.1	33.3 (57.7)
Ostrya virginiana	hophornbeam	500.0 (100.0)	233.3 (208.2)	0
Pinus echinata	shortleaf pine	1200.0 (1442.2)	0	0
Prunus serotina	black cherry	1342.9 (785.0)	228.6 (398.8)	71.4 (95.1)
Quercus alba	white oak	2160.0 (3100.5)	140.0 (260.8)	20.0 (44.7)
Quercus marilandica	blackjack oak	50.0 (70.7)	50.0 (70.7)	0
Quercus rubra	red oak	150.0 (238.0)	175.0 (150.0)	50.0 (57.7)
Quercus stellata	post oak	366.7 (404.1)	33.3 (57.7)	0
Red oak group	red oak group	1257.1 (556.3)	71.4 (95.1)	0
Robinia pseudoacacia	black locust	3100.0	0	0
Sassafras albidum	sassafras	100.0	0	0
Ulmus alata	winged elm	75.0 (95.7)	300.0 (336.7)	25.0 (50.0)
Viburnum rufidulum	rusty blackhaw	100.0	0	0
White oak group	White oak group	375.0 (221.7)	25.0 (50.0)	0

Sapling regeneration was a mix of both xeric and mesic species, but dominated by black hickory (mean density of 800 ± 809.3 and 400 ± 561.2 individuals in the small and large sapling classes, respectively). Again the mixed xeric and mesic characteristics of the forest sites were reflected in the composition and density of the regeneration layer.

Discussion

The oak-hickory-pine forests of the Sugarloaf Mountain area at HOSP are indicative of forested areas across the Ouachita Mountains in Arkansas. Overstory composition and structure reflect a forest affected by changes in the natural disturbance regime as well as a history of anthropogenic disturbances (e.g., logging). A combination of natural fires along with topo-edaphic features traditionally maintained the forest in a late seral stage, dominated by shortleaf pine and a mix of xeric and mesic oak species distributed according to slope position, aspect, exposure, and soil depth. At HOSP it is important to keep in mind that the natural resources are managed with a general goal of providing a natural backdrop for the hot springs and a specific goal of protecting the shortleaf pine stand on Sugarloaf Mountain (NPS, 1986). In addition, the promotion of shortleaf pine regeneration and succession of the oak-hickory-pine forest may be included as a

broader context for preserving the identified pine stand. It is this broader context for which HTLN vegetation monitoring was undertaken at HOSP in 2007. Network vegetation monitoring complements the monitoring efforts of the Ozark Highlands Fire Effects Monitoring Module that was started in 2006.

The establishment of persimmon and sassafras indicate a change in the fire regime for the area allowing for the growth of more shade tolerant tree species. To address this change, prescribed fire returned to the Sugarloaf Mountain area in 2006 after a 20 year absence. The goal of re-introducing fire to the area is to promote the regeneration of shortleaf pine and create structural pathways to allow recruitment of shortleaf pine into larger size classes and upper layers of the canopy. This fire monitoring objective overlaps with HTLN vegetation monitoring at HOSP.

As reported here and previously (Dale and Ware, 1999), shortleaf pine are distributed across the Sugarloaf Mountain area regardless of aspect or elevation. Furthermore, it is a measurable component of the regeneration layer. Shortleaf pine was found in the dominant canopy and sub-canopy in all but a single monitoring site. Therefore the goal of promoting shortleaf pine regeneration has partially been achieved through natural processes. However, no shortleaf pine saplings were detected in either of the two regeneration size classes.

Natural pathways for succession currently are in place across the Sugarloaf Mountain area. Areas currently dominated by xeric oak species or mesic oak and hickory species in the overstory will tend to persist. While nearly all areas have shortleaf pine, the abundance, size, and recruitment of this species is dependent on topo-edaphic features that promote the growth of certain oak and hickory species at a local scale. While increased prescribed fire or reduced fire suppression may benefit shortleaf pine, an alternate goal of a functioning oak-hickory-pine forest may be more beneficial from both a management and natural resource standpoint.

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Appendix

Appendix A. Frequency (%) and mean foliar cover (%) for understory herbaceous species among all sites sampled in 2007 (n=7).

Scientific Name	Common Name	Frequency	Mean Cover
Acalypha gracilens	Ozarkian short-stalk copperleaf	1.4	0.50
Amphicarpa bracteata	Hog-peanut	17.1	0.50
Antennaria plantaginifolia	Plantain pussytoes	4.3	0.50
Andropogon virginicus	Broom-sedge	2.9	0.50
Aristolochia serpentaria	Snakeroot	8.6	0.92
Aralia spinosa	devil's walkingstick	4.3	1.33
Asclepias spp		1.4	0.50
Aster patens	Clasping wild aster	2.9	0.50
Asplenium platyneuron	Ebony spleenwort	14.3	0.50
Aster spp		12.9	0.50
Callicarpa americana	American beautyberry	1.4	3.00
Carex spp		25.7	0.64
Camassia scilloides	Wild hyacinth	1.4	0.50
Clitoria mariana	Atlantic pigeonwings	2.9	7.75
Cocculus carolinus	Carolina moonseed	2.9	0.50
Cunila origanoides	common dittany	10.0	0.50
Danthonia spicata	Poverty oatgrass	5.7	0.50
Desmodium nudiflorum	Naked tick-trefoil	25.7	0.50
Diarrhena americana	American beakgrain	1.4	0.50
Dichanthelium boscii	Panic grass	5.7	0.50
Dichanthelium spp		10.0	0.50
Dioscorea villosa	Colic-root	24.3	1.94
Erechtites hieraciifolia	Fireweed	5.7	0.50
Euphorbia corollata	Flowering spurge	21.4	0.50
Galium arkansanum	Bedstraw, cleavers	4.3	0.50
Galium circaezans	Forest bedstraw, wild licorice	4.3	0.50
Heuchera americana	American alumroot	1.4	0.50
Helianthus divaricatus	woodland sunflower	20.0	0.68
Hieracium gronovii	Beaked hawkweed	7.1	0.50
Ilex opaca	American holly	1.4	0.50
Iris cristata	dwarf crested iris	4.3	1.33
Lactuca serriola	Prickly lettuce	1.4	0.50
Lathyrus venosus	Forest pea	1.4	0.50
Lespedeza procumbens	Downy trailing lespedeza	1.4	0.50
Lespedeza violacea	Violet lespedeza	1.4	0.50
Lonicera spp		1.4	0.50
Menispermum canadense	Moonseed	7.1	0.50
Monarda spp	beebalm	18.6	1.27
Parthenocissus quinquefolia	Virginia-creeper, woodbine	34.3	1.54
Phlox spp		7.1	0.50
Piptochaetium avenaceum	blackseed speargrass	21.4	2.93
Pleopeltis polypodioides	resurrection fern	7.1	0.50
Pteridium aquilinum	Bracken fern	8.6	1.33
Rhus aromatica	Squaw-bush	7.1	3.90

Rosa carolina	Pasture rose	7.1	1.00
Rubus spp		24.3	1.79
Ruellia pedunculata	stalked wild petunia	8.6	0.50
Sanicula spp	sanicle	2.9	0.50
Scutellaria ovata	Forest-skullcap	10.0	3.29
Sideroxylon lanuginosum	Carolina buckthorn	1.4	0.50
Smilax bona-nox	saw greenbrier	38.6	0.59
Smilax tamnoides	Catbrier	1.4	0.50
Solidago spp		32.9	0.50
Symphoricarpos orbiculatus	Coralberry	4.3	0.50
Toxicodendron radicans	Common poison-ivy	45.7	4.33
Vaccinium spp	blueberry	51.4	6.00
Vitis aestivalis	summer grape	21.4	5.53
Viola spp		1.4	0.50
Viburnum prunifolium	Black haw	1.4	0.50
Vitis rotundifolia	muscadine	54.3	2.45
Viburnum rufidulum	Southern black haw	7.1	4.40
Vitis spp		1.4	0.50

The NPS has organized its parks with significant natural resources into 32 networks linked by geography and shared natural resource characteristics. HTLN is composed of 15 National Park Service (NPS) units in eight Midwestern states. These parks contain a wide variety of natural and cultural resources including sites focused on commemorating civil war battlefields, Native American heritage, westward expansion, and our U.S. Presidents. The Network is charged with creating inventories of its species and natural features as well as monitoring trends and issues in order to make sound management decisions. Critical inventories help park managers understand the natural resources in their care while monitoring programs help them understand meaningful change in natural systems and to respond accordingly. The Heartland Network helps to link natural and cultural resources by protecting the habitat of our history.

The I&M program bridges the gap between science and management with a third of its efforts aimed at making information accessible. Each network of parks, such as Heartland, has its own multi-disciplinary team of scientists, support personnel, and seasonal field technicians whose system of online databases and reports make information and research results available to all. Greater efficiency is achieved through shared staff and funding as these core groups of professionals augment work done by individual park staff. Through this type of integration and partnership, network parks are able to accomplish more than a single park could on its own.

The mission of the Heartland Network is to collaboratively develop and conduct scientifically credible inventories and long-term monitoring of park "vital signs" and to distribute this information for use by park staff, partners, and the public, thus enhancing understanding which leads to sound decision making in the preservation of natural resources and cultural history held in trust by the National Park Service.

www.nature.nps.gov/im/units/htln/

Heartland Network

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