

Delineation of Old-Growth Oak and Eastern Hemlock in Great Smoky Mountains National Park

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Editor's Note: The Great Smokies old-growth baseline data study was funded through NRPP (Natural Resources Preservation Program) monies as an inventory and monitoring project and was the first of its kind within the park.

In response to the southerly spread of two exotic forest pests, the gypsy moth (*Lymantria dispar* (L.)) and the hemlock woolly adelgid (*Adelges tsugae* Annand), Great Smoky Mountains NP, Resource Management and Science Division, initiated the Old-Growth Project to identify and map the park's old-growth oak (*Quercus* spp.) and eastern hemlock (*Tsuga canadensis* (L.) Carr.) forests and to establish long-term vegetation monitoring plots within these areas. Identification and mapping of representative stands is now complete and establishment of long-term monitoring plots is beginning.

Stand Location and Delineation

We located the old-growth hemlock and oak forests using current Geographic Information Systems (GIS) data (Pyle

1985, MacKenzie 1991) and recent aerial photography (1:12,000 scale) in conjunction with historical information, old photographs, previous vegetation studies, reports of anthropogenic disturbance, and interviews with persons knowledgeable in early pre-park history. We selected a minimum stand size of 5 hectares (ha) for hemlock; a minimum stand size was not used for oak forests due to their small size and patchy distribution (smallest delineated area equaled 2 ha). Each potential site was ground truthed and mapped. We conducted a minimum of two arbitrarily

placed canopy tree tallies in each stand using approximately 1/10-ha circular areas to tally species, relative frequency, crown class, and regeneration. The tally information was used to estimate canopy dominance, species composition, and to verify forest types (see table 1 for forest type descriptions). We determined the old-growth forest type by the species or species association with the highest (minimum 50% frequency) representation in the dominant and codominant canopy classes. We took increment cores and

Table 1. Description of Forest Types Used for Delineation

Mesic Oak

Within the park, these forests occur at middle to upper elevations from 1,585-1,067 m (3,500-5,200 ft) on gently sloping ridge crests with south, east, or west aspects, and at lower elevations from 763-1,372 m (2,500-1,800 ft) on nearly flat south aspects. At the higher elevations northern red oak is dominant, with canopy associates of white oak (*Quercus alba* L.), chestnut oak (*Quercus prinus* L.), red maple, eastern hemlock, and Carolina silverbell. Mesic oak forest at lower elevations is dominated by chestnut oak associated with red maple, black gum (*Nyssa sylvatica* Marsh.), pignut hickory (*Carya glabra* (P. Mill.) Sweet), and black birch (*Betula lenta* L.). In both cases, oak species comprise 50% or more of the upper canopy (per canopy tree tally). The understory community includes sweetshrub (*Calycanthus floridus* L.), maple-leaf viburnum (*Viburnum acerifolium* L.), azaleas (*Rhododendron* spp. L.), and witch-hazel (*Hamamelis virginiana* L.).

Submesic Oak

These forests occur on moderate middle elevation 763-1,372 m (2,500-4,500 ft) slopes, with southerly aspects or on nearly flat north-facing ridge tops in the western end of the park. These ecosystems are dominated by chestnut oak, northern red oak, and red maple, and oak species comprise 50% or more of the upper canopy layers (per tree tally). The understory is dominated by deciduous ericads—primarily huckleberries (*Gaylussacia* spp. Kunth), blueberries (*Vaccinium* L.), and azaleas.

Subxeric Oak

These forests are dominated by chestnut oak, scarlet oak (*Quercus coccinea* Muenchh.), and black oak (*Quercus velutina* Lam.), which comprise 50% or more of the upper canopy (per tree tally). Pines (*Pinus* spp. L.) often mix with the hardwoods. The understory component is primarily mountain laurel (*Kalmia* spp. L.), with other ericads such as blueberries, huckleberries, and rhododendron (*Rhododendron* spp. L.).

Xeric Oak

Blackjack (*Quercus marilandica* Muenchh.), scarlet, and chestnut oaks are common on these dry, often south-facing areas. Oak species represent 50% or more of the upper canopy. Virginia pine (*Pinus virginiana* P. Mill), pitch pine (*Pinus rigida* P. Mill), and Table Mountain pine (*Pinus echinata* P. Mill) often share the canopy, along with sourwood (*Oxydendrum arboreum* (L.) DC.), black gum, and red maple. Blueberries and mountain laurel generally occupy the shrub layers.

Hemlock/Cove Hardwoods

These forests generally occur on moist, north-facing slopes to about 1,219 m (4,000 ft) in elevation. Hemlock dominates the upper canopy, and hardwood associates include tulip-poplar, black birch, yellow birch, and Fraser magnolia. The understory is typically dense rosebay rhododendron (*Rhododendron maximum* L.) and dog-hobble (*Leucothoe* spp. D. Don).



Researchers using increment coring tools examined 700 trees throughout the study area in order to confirm the presence of old-growth. Increment coring is a common technique for aging trees by counting growth rings.

Delineation of Old-Growth Oak and Eastern Hemlock (cont'd)

diameters at breast height from a minimum of two trees per tally site, and noted old-growth characteristics and anthropogenic disturbance (see tables 2 and 3 for criteria). Additional increment core data—taken on the location of potential old-growth stands and in areas of suspected disturbance—were essential for verifying tree ages and releases in annual growth. We considered a minimum age of 150 years a coarse filter for old-growth candidacy, as the lower valleys were cleared for agriculture and timber as early as 1840 (Trout 1987).

Results and Discussion

We located and mapped 86 stands, totalling 926 ha, as summarized by forest type in table 4. The stands were distributed throughout the park, although oak types tended to be concentrated in the western portion and hemlock types in the eastern portion. In general, the hemlock

stands represented relatively undisturbed areas; oak areas exhibited a higher level of disturbance, especially due to the loss of the American chestnut (*Castanea dentata* (Marsh) Borkh.). With the exception of xeric oak, we located representative stands in all of the oak and hemlock forest types considered in this project, although we delineated only one small (2 ha) stand in subxeric oak. In the remaining forest types—mesic oak, submesic oak, hemlock/northern hardwoods, and hemlock/cove hardwoods—stands with both high and moderate virgin forest attribute ratings were delineated and are available for permanent plot location.

Technique

Hardwood forest types of the eastern and southern United States are highly variable (Avery 1978), and infrared aerial photo interpretation of old-growth forests proved difficult within our study area. We

did not determine a reliable, consistent photo identification pattern of forest types, due in part to the seasonal differences in photo sets and the wide range of color variation between prints on the same flight line. Images at the edges of stereo pairs were inherently distorted and hemlock canopy dominance was visually exaggerated within these areas. In contrast with hemlock, old-growth oak in our project areas could not be reliably determined by photo characteristics. For example, areas with old-growth characteristics such as large flat-topped crowns were generally younger (60-120 years), than vigorous northern red oaks (*Quercus rubra* L.) or second-growth forest. Areas on the photos that appeared as canopy gaps were often rocky areas, cliffs, or steep changes in elevation, and could not be considered indicators of old-growth based solely on the photo image.

Initially, we used a composite GIS map of areas lacking known human disturbance (Pyle 1985) overlaid with predicted forest cover types (MacKenzie 1991) to locate old-growth oak. Ground truthing revealed that oak forest type predictions were fairly accurate but that human disturbance records were not consistently reliable. Old-growth mesic oak was particularly over-predicted, and submesic oak was often of old-growth character inside and outside the predicted areas.

Experience in each forest type has led us to realize that one old-growth characteristics rating system is not applicable to all forests in the park, and forest type-specific rating methods need to be developed. As an example, attributes that were rated higher in our mesic oak forests, such as pit-and-mound microtopography, were rated lower in submesic stands where the trees typically rot and decay without uprooting. The lower rating was not due to a lack of old-growth integrity but perhaps to a difference in soils and windthrow characteristics. Modifications might include quantifying each old-growth attribute or "weighing" human disturbance more heavily than other attributes.

The 150-year-minimum age for old-growth—intended to "filter out" most European influence in the park—tended to exclude old-growth ecosystems with a severe or regular disturbance regime because they lacked the project's old-growth characteristics, such as consistent "old" ages and uneven-aged structure. In addition, "virgin" forests recovering from extensive disturbances, including wind and ice storms, chestnut blight, or forest fires could have been excluded if the disturbance occurred after the 1840s.

Table 2
Old-growth Characteristics

Listed attributes rated in all forest types except oak specific (++) and hemlock specific (*).

- Logs in all stages of decomposition
- Standing snags
- Majority of canopy tree ages 150 years or greater
- Canopy gaps (log present in some stage of decay)
- Little evidence of human disturbance
- Pit and mound microtopography
- High amount of woody debris on ground and in associated streams
- Old bark characteristics of canopy trees
- Bole and root decay
- Canopy structure multilayered (uneven-aged or in a series of age classes ++)
- Flat-topped tree crowns ++
- Undisturbed soil *
- Uneven-aged structure *
- Large trees (relative to site) *
- Large commercially important tree species of high quality *
- Rounded tree crowns in profile *

Table 3
Disturbance Rating Classes

High in virgin forest attributes (A): the stand retained natural structure with little or no record or evidence of human disturbance.

Moderate in virgin forest attributes (B): the stand generally retained natural structure with record of evidence of selective logging or chestnut blight.

Low in virgin forest attributes (C): the stand retained scattered old-growth trees with record or evidence of extensive disturbance due to logging or chestnut blight.

Adapted from Pyle 1985.

Table 4

Delineated Area Totals by Forest Type

Total survey area: 959 ha*

	Oak Types (665 ha)(294 ha)		Hemlock Types			
	Mesic	Submesic	Subxeric	Hem/Cove	H e m /	
North						
Total ha per type		212	451	2	247	47
# stands surveyed		21	39	1	19	6
Avg. stand size	10	12	2	14	8	
% Total	22	47	0.2	26	5	

*Areas displayed in this table are not adjusted to scale for slope.

Table 5

Forest Type Comparisons Based on Canopy Tree Tallies

Hemlock Type: Hemlock/Cove Hemlock/North

Species	Comp%	Canopy%	Comp%	Canopy%
<i>Betula alleghaniensis</i>	6.4	4.9	8.6	3.6
<i>Acer rubrum</i>	3.7	3.9	3.9	3.6
<i>Magnolia fraseri</i>	2.8	2.3	8.9	1.5

Oak Type: mesic submesic subxeric mesic submesic subxeric

Species	% Composition			% Upper Canopy		
<i>Quercus rubra</i>	30.0	14.6	0.9	50.6	20.0	2.0
<i>Quercus prinus</i>	4.0	22.6	23.4	7.7	34.9	31.4
<i>Quercus velutina</i>	0.1	3.1	8.1	0.2	3.9	5.9
<i>Quercus coccinea</i>	0.4	2.0	14.4	1.1	3.1	27.5
<i>Quercus</i> spp. total	40.8	49.1	54.0	67.7	72.8	82.4

Through the collection of 748 complete (readable, to center, and lacking rot) core samples, we determined that bark characteristics did not always indicate relative age. For both hemlock and oak, old (exceeding 150 years) suppressed trees had "young" bark characteristics, and young vigorous trees had the very rough and furrowed bark usually associated with old trees. In addition, we found some species with atypical bark characteristics, and some species such as American beech (*Fagus grandifolia* Ehrh.), Fraser magnolia (*Magnolia fraseri* Walt.), and American holly (*Ilex opaca* Ait.) may never develop rough bark.

Tree Tally Information Summary

The following information is based on arbitrarily placed canopy tree tally areas and should be considered preliminary; data from the permanent monitoring plots will be necessary to substantiate or refine these observations.

Two types of eastern hemlock forests were surveyed in this project: Hemlock-Cove hardwoods and Hemlock-Northern hardwoods. Within our study area, preliminary information suggests considerable compositional differences between the two types (table 5). Some patterns, however, appeared common to both forest types. Species such as Fraser magnolia, yellow birch (*Betula alleghaniensis* Britt.), and silverbell (*Halesia tetraptera* var. *monticola* Ellis) had a low recruitment to the upper canopy, based on their total compositional value. In contrast, red maple (*Acer rubrum* L.) was relatively even in distribution throughout the canopy. Hemlock was more frequent in the suppressed canopy class, which may indicate that suppressed hemlock saplings were distributed evenly throughout the lower canopy (therefore, well represented in the tally data), whereas suppressed hardwoods were only well represented in scattered canopy gaps.

In both types, hardwoods dominated the intermediate canopy class.

We differentiated three types of oak forests based on overall canopy composition related to exposure and elevation (Whittaker 1956). Oak dominated all types and varied considerably in composition as well as in the canopy distribution of species in each. Oak increased in compositional value as a component of the forest as a whole and within upper canopy layers as aspects became more exposed and better drained. Overall, oaks (aside from northern red) increased in composition from mesic to subxeric sites.

Summary

Currently, 959 ha of old-growth oak and hemlock stands are delineated in the Smokies, and permanent monitoring plots will continue to be established through the 1994 field season. The baseline data will provide information for the definition and understanding of these ecosystems, and are valuable as a preinfestation reference for future pest management decisions.

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