Attachment 38

Comments on the Draft Plan submitted by Objectors on June 29, 2020, along with all attachments

# Nantahala Pisgah Draft Forest Plan Comments – Attachments

Attachment 01 Identification of Canopy Gap and Early Successional Habitat Patches on the Nantahala and Pisgah National Forests

Attachment 02 Procedure for Estimating the Natural Range of Variation (NRV) Nantahala and Pisgah National Forests – January 2015

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Attachment 04 Spectrum Coefficients for YoungGap creation

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Attachment 06 Belowground Ecology and Dynamics in Eastern Old-Growth Forests

Attachment 07 Old-growth red spruce forests as reservoirs of genetic diversity and reproductive fitness

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Attachment 01

# Identification of Canopy Gap and Early Successional Habitat Patches on the Nantahala and Pisgah National Forests

# Identification of Canopy Gap and Early Successional Habitat Patches on the Nantahala and Pisgah National Forests

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Last updated 8/10/2017

**Introduction:**

The Nantahala and Pisgah National Forests' (hereafter, the Forests) Plan Revision Assessment (hereafter, the Assessment) highlighted the current condition of under-represented young forest across all ecozones on both NFS and other lands in the planning area. The Assessment states:

> *Over the last fifteen years on the national forests the amount of mature and old forest has increased, while the amount of very young forest – also known as early successional habitat and calculated based on 0-10 year old regenerated stands - has decreased from 3.0% to 0.6% of the national forests, from 31,026 acres to 6,244 acres.*

Under-representation of early successional habitat (ESH) is a conservation concern for the Forests because of implications of this deficit on plant and animal species that rely on early successional habitats for all or part of their life history. Examples of such species include the Golden-winged Warbler, White-tailed Deer, Elk, Ruffed Grouse, and multiple plant species of conservation concern, including mountain catchfly and a host of other sun-loving plant species. Acres of the forest with various canopy cover classes were calculated as part of the Assessment; however, there is a need to take that analysis deeper to identify gaps in the canopy that could represent areas of openings and early successional forest.

This analysis utilizes the existing LiDar-derived vegetation structural data to identify gaps in the canopy, and assesses the composition and spatial configuration of such gaps across the 18-county area used for the assessment. Results from this analysis may be used to support decisions on future restoration and forest management projects by identifying existing gaps that could provide desired habitat, and where those gaps may be maintained, as well as identifying areas where gaps are less prevalent but may need to be created for species restoration.

Questions that can be answered by this data summarization and analysis include, but are not limited to:

- How much of the Forest consists of gaps? How are those gaps characterized, in terms of spatial configuration (e.g. size, shape) and distribution? And how do these gaps contribute to open forest and/or young forest (YF)/ESH conditions on the landscape?

- Is there a difference in the number and/or size of gaps between ecozones? Are some ecozones prone to more gaps than others? Are there ecozones that have fewer gaps than would be expected under natural disturbance regimes?

- Are there areas on the landscape where gaps are more or less prevalent?

- Is there a difference in the number and/or size of gaps in wilderness areas versus the non-wilderness or managed NFS lands? If so, what are the differences?

It is important to note that some of these questions require integration with other analyses such as Potential Natural Vegetation (PNV) modeling, Natural Range of Variation (NRV) estimation and Spectrum analysis of projected change in forest conditions over time.

**Methods**

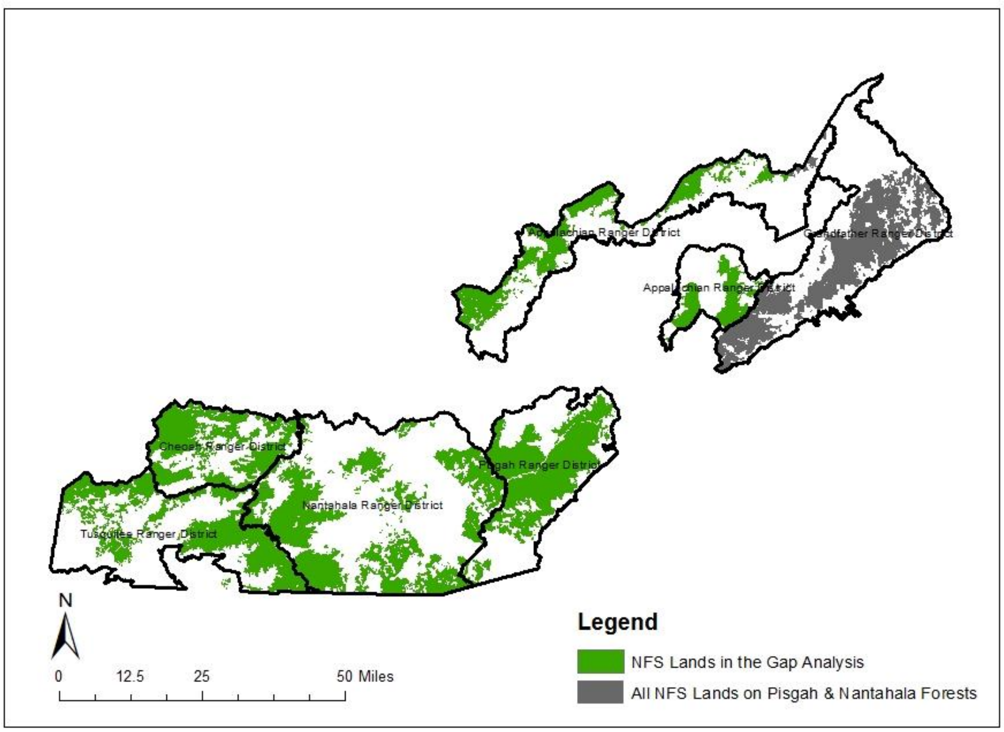
To identify canopy gaps, we used the most precise, full-coverage vegetation data available, which is the LiDar data that was developed in 2005. The dataset has good accuracy with canopy height and cover, and good precision, as the pixel size is 40'x40' (or <0.01 acre). However, the data layer is dated, and thus this analysis should be interpreted as a "snapshot in time" of where canopy gaps occurred on the Forests in 2005. The biggest assumption here is that gap creation and loss/closure have been happening at the same rate since 2005. New LiDar data is expected to be available in 2018, at which time the analysis could be re-run to compare changes in the past decade.

LiDar data does, however, have inherent limitations, and thus should be interpreted with those limitations in mind. For example, it is unable to discern what ground cover composition is from the data. Identified canopy gaps could be grassy, providing grazing habitat for herbivores, or they could be covered in leaf litter or rock or gravel, providing different habitat characteristics or quality. Similarly, tree canopy and shrub layer composition cannot be assessed from LiDar data. Vegetative composition is critical to hard and soft mast-dependent species such as many migratory birds and small mammals, Black Bear, Wild Turkey, and Ruffed Grouse.

Additionally, a portion of the Forests was not included in the 2005 LiDar data collection. Part of the Grandfather Ranger District had LiDar collected in Phase 2 (prior to 2005) and the results are of lower quality, and therefore not comparable with the Phase 3 data. Therefore, the areas without Phase 3 data were eliminated from this analysis. Results will need to be extrapolated to the areas with no data, with an understanding that accuracy will be decreased and not site-specific for those areas, or the analysis re-run with new LiDar data once it is available. However, this is not expected to happen until plan revision is complete, so the 2005 Phase 3 LiDar data is considered to be the best available information at the time of this analysis.

In summary, this analysis included all NFS lands that have Phase 3 LiDar data available, approximately 846,572 acres (Figure 1).

*Figure 1. National Forest System (NFS) lands used in the canopy gap analysis for the Nantahala and Pisgah National Forests.*




Details of the GIS processing steps that were taken to identify gaps are attached as an appendix to this document. The steps below explain key processes of this analysis:

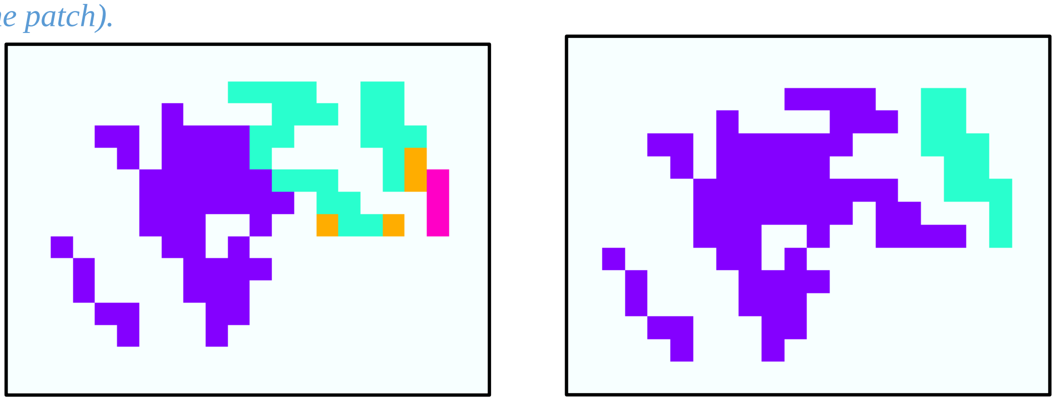
1. Canopy gaps were defined ecologically as *places where the canopy is open and the trees and shrubs are small enough and their density is low such that sunlight is able to reach the forest floor, providing potential habitat for species (plants and animals) that prefer such open conditions*. From the LiDar data, this is identified as pixels exhibiting the following characteristics: *Canopy Cover 0-25% AND Tree Height 0-15 feet AND Shrub Density <50%.*

2. To reduce extreme patchiness of the data, the Aggregate Function was used to create a reduced-resolution raster that took the mean value for an 80'x80' pixel, and then to identify patches based on an 8-pixel neighbor grouping (i.e. if two pixels were touching on any sides or corners, they were considered part of the same patch) (Figure 2).

3. Canopy gap patches were intersected with the Nantahala-Pisgah PNV model to identify ecozone values, based on which ecozone represented the majority of the canopy gap patch (Figure 2).

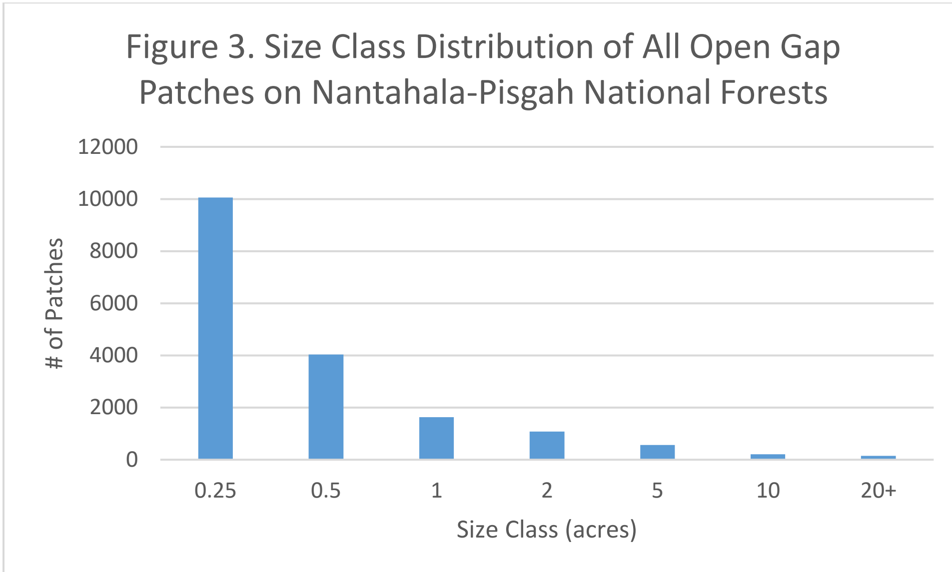
4. Canopy gap patches were converted from rasters to polygons, and associated data was exported to Microsoft Excel for summarization and presentation (however, spatial presentation is still needed for parts of this process).

*Figure 2. Example of multiple ecozones within the same patch (left), which were aggregated into patches based on the majority ecozone (right). Three patches total were created, based on the "eight neighbor rule" (i.e. pixels have to be touching on a side or corner to be considered the same patch).*

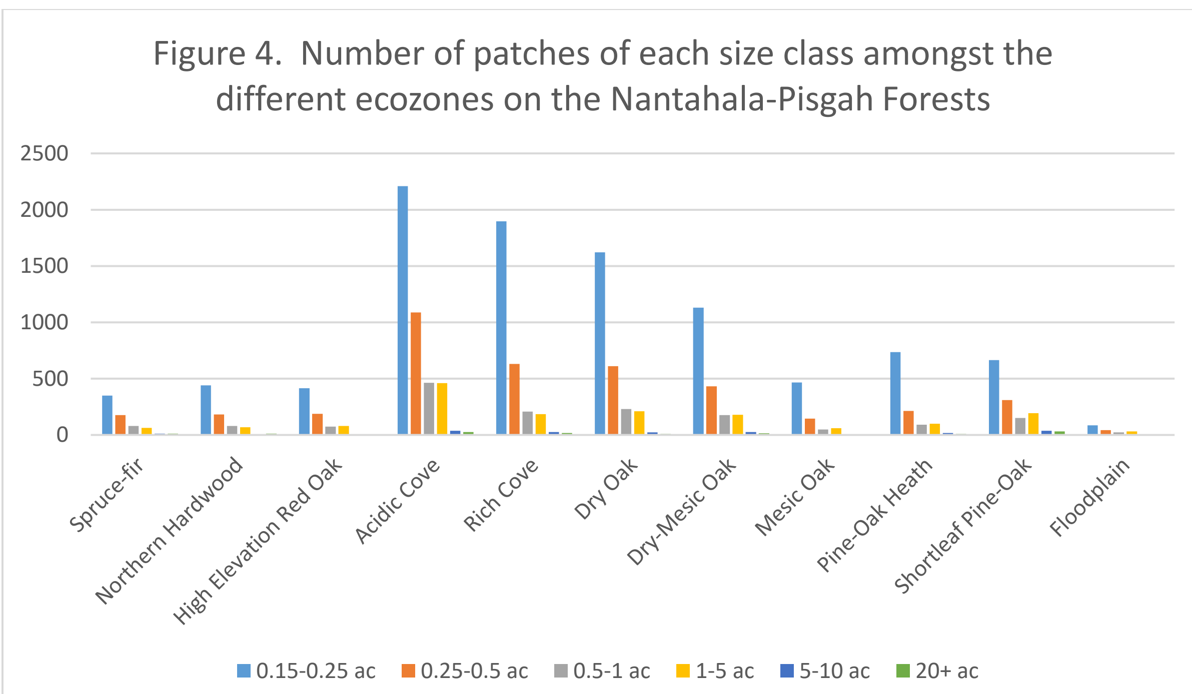


**PRELIMINARY RESULTS**

Approximately 18,000 canopy gap patches, totaling approximately 13,000 acres, were identified on the Forests (approximately 1.5% of the analysis area, keeping in mind that only Phase III LiDar was used) (Table 1). The majority of canopy gap patches (approximately 80%) were 0.5 acres or less in size, and approximately 5% were 5 acres or larger, with the largest being 747 acres (Black Balsam/Sam's Knob area on the Pisgah Ranger District) (Figure 3).




Canopy gap patches occurred in all ecozones, and the size distribution was similar to that shown above for all gaps (Figure 2). Across ecozones, smallest patches were the most prevalent, and larger patches (1 acre or larger) were rare (Figure 4).




The Acidic Cove ecozone had the greatest number of gaps, as well as the greatest amount of acreage in gaps (Table 1). Ecologically this may seem strange, since coves are usually fairly protected from disturbances that would cause gaps. However, the Acidic Cove is the most prevalent ecozone in the analysis area. To understand the proportion of each ecozone that is a gap, we looked at the acres of gap habitats within each ecozone relative to the amount of that ecozone on the landscape. That gave a different picture, one that is perhaps more expected (Table 1, last column).

*Table 1. Gap patches by ecozone on the Nantahala-Pisgah Forests, showing the total number of patches, the total acres of gap patches, average patch size (and standard deviation), and proportion of the ecozone that is a gap.*

| **Ecozone**<br>(acres in analysis area) | **# of Gap Patches** | **Total Acres of Gap** | **Avg. Patch Size** | **% of Ecozone that is Gap** |
|---|---|---|---|---|
| **Spruce-fir** (15,649) | 691 | 1,288 | 1.9 | 8.2 |
| **Northern Hardwood** (48,304) | 787 | 710 | 0.9 | 1.5 |
| **High Elevation Red Oak** (38,176) | 767 | 417 | 0.5 | 1.1 |
| **Acidic Cove** (182,119) | 4,282 | 2,764 | 0.6 | 1.5 |
| **Rich Cove** (165,630) | 2,961 | 1,631 | 0.6 | 1.0 |
| **Dry Oak** (156,661) | 2,704 | 1,532 | 0.6 | 1.0 |
| **Dry-Mesic Oak** (86,986) | 1,956 | 1,223 | 0.6 | 1.4 |
| **Mesic Oak** (41,216) | 730 | 342 | 0.5 | 0.8 |
| **Pine-Oak Heath** (61,288) | 1,215 | 785 | 0.6 | 1.3 |
| **Shortleaf Pine-Oak** (31,568) | 1,391 | 1,662 | 1.2 | 5.3 |
| **Floodplain** (1,089) | 193 | 273 | 1.4 | 25.0 |
| **Grassy Bald** (517) | 28 | 188 | 6.7 | 36.4 |
| **All** | 17,705 | 12,814 | 0.7 | |

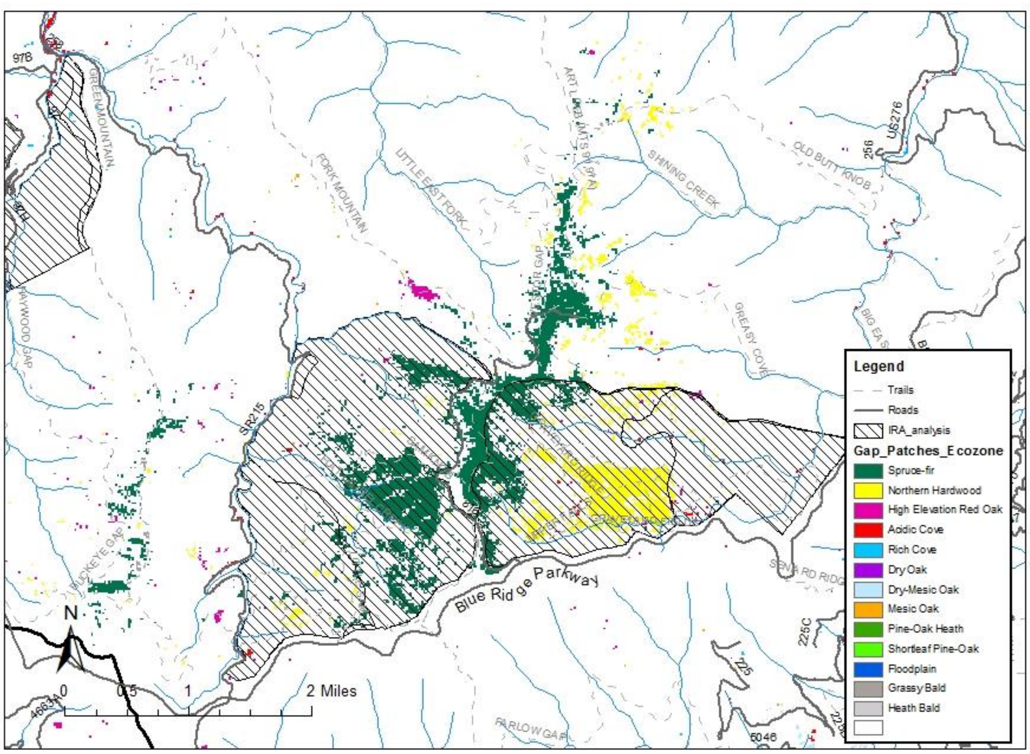
*Table 2. Relative ranking of ecozones in relation to the amount of gaps within the ecozone. The first column shows rank by the total number of acres, second column is by the total number of patches, and the third column shows the proportion of the ecozone that is a gap.*

| **Rank** | **Total Acres of Gaps** | **Total # Gap Patches** | **Relative Proportion of Ecozone that is Gap** |
|---|---|---|---|
| 1 | Acidic Cove | Acidic Cove | Grassy Bald |
| 2 | Shortleaf Pine-Oak | Rich Cove | Floodplain |

| | | | |
|---|---|---|---|
| 3 | Rich Cove | Dry Oak-Deciduous Heath | Spruce-Fir |
| 4 | Dry Oak | Dry Mesic Oak | Shortleaf Pine-Oak |
| 5 | Spruce-Fir | Shortleaf Pine-Oak | Acidic Cove |
| 6 | Dry-Mesic Oak | Pine-Oak Heath | N. Hardwood |
| 7 | Pine-Oak Heath | N. Hardwood | Dry-Mesic Oak |
| 8 | N. Hardwood | High Elev. Red Oak | Pine-Oak Heath |
| 9 | High Elev. Red Oak | Mesic Oak | High Elev. Red Oak |
| 10 | Mesic Oak | Spruce-fir | Rich Cove |
| 11 | Floodplain | Floodplain | Dry Oak |
| 12 | Grassy Bald | Grassy Bald | Mesic Oak |

The two smallest ecozones, grassy balds and alluvial floodplains, had the highest proportion of the ecozone in a gap structural state (Table 2). These ecozones both are prone to open conditions due, so this is not surprising. Two of the high elevation ecozones (spruce-fir and northern hardwood,) were among the highest in terms of relative proportion of the ecozone in gap states. These ecozones contain the largest canopy gap patch (approximately 747 acres) on the Forests (Figure 3).

*Figure 3. Large gap at Black Balsam/Sam's Knob area on the Pisgah Ranger District in spruce-fir ecozone.*



**Other Early Stand Habitat Patches**

Using the same methods as used to identify canopy gap patches, patches of Early Successional Habitat (ESH) were identified similar to canopy gap patches, except that the canopy density was greater than 25%, indicating a stand that is starting to fill back in after a disturbance. We identified two kinds of ESH patches: ESH Moderate (canopy cover 25-60%) and ESH Dense (canopy cover >60%).

There were substantially more patches and more acres of the ESH types than there were the open canopy gap patches (Table 5). Similar to canopy gap patches, these ESH patches were primarily small, isolated patches across the Forest, many of which are likely the result of single-tree falls that are growing back in quickly with vegetation, leading to the higher canopy cover.

*Table 5. Size of ESH) patches across the Nantahala and Pisgah National Forests.*

| Acres | ESH Mod | ESH Dense | Total # Patches | % of all patches |
|---|---|---|---|---|
| 0-0.15 | 53,188 | 96,604 | 149,792 | 75 |
| 0.15-0.3 | 13,088 | 14,996 | 28,084 | 14 |
| 0.3-0.5 | 5,485 | 3,845 | 9,330 | 5 |
| 0.5-1 | 5,649 | 2,038 | 7,687 | 4 |
| 1-2 | 2,407 | 274 | 2,681 | 1 |
| 2-5 | 881 | 26 | 907 | <1 |
| 5-10 | 135 | 4 | 139 | <1 |
| 10-20 | 13 | 1 | 14 | <1 |
| >20 | 1 | 1 | 2 | <1 |
| **Total** | **80,847** | **117,789** | **198,636** | **100** |

Overall there were acres of 46,836 acres of ESH in the analysis area, representing approximately 5.5% of the analysis area. As was the case canopy gap patches, the floodplain and grassy bald ecozones had the greatest proportion of their area in ESH. Overall, the proportion of the ecozones that are ESH is much higher than the proportion that is a Gap (compare Table 1 with Table 6).

*Table 6. Total acres of Early Stand Habitat (ESH) by ecozone in the analysis area, and the proportion of each ecozone that was in ESH in 2005.*

| | **ESH Dense** | **ESH Moderate** | **Grand Total** | **% of Ecozone that is ESH** |
|---|---|---|---|---|
| **Spruce-fir** | 399 | 1,051 | 1,451 | 9.3 |
| **Northern Hardwood** | 909 | 1,271 | 2,180 | 4.5 |
| **High Elevation Red Oak** | 837 | 1,322 | 2,159 | 5.7 |
| **Acidic Cove** | 4,951 | 4,827 | 9,778 | 5.4 |
| **Rich Cove** | 4,514 | 4,057 | 8,570 | 5.2 |
| **Dry Oak** | 3,831 | 4,157 | 7,988 | 5.1 |
| **Dry-Mesic Oak** | 2,649 | 2,772 | 5,421 | 6.2 |
| **Mesic Oak** | 928 | 1,109 | 2,036 | 4.9 |
| **Pine-Oak Heath** | 1,678 | 2,375 | 4,053 | 6.6 |
| **Shortleaf Pine-Oak** | 1,214 | 1,660 | 2,874 | 9.1 |
| **Floodplain** | 92 | 128 | 221 | 20.3 |
| **Grassy Bald** | 53 | 51 | 104 | 20.1 |
| **All** | 22,056 | 24,780 | 46,836 | |

ATTACHMENTS:

Appendix 1: Canopy Gap Patch identification steps

Appendix 2: Early Successional Habitat Patch identification steps

****This process should be updated as further analysis and summarization of gap data is completed****

# Gap Analysis

Thursday, March 17, 2016

12:45 PM

This document details the GIS processing steps that were taken to identify "Gaps" on Nantahala-Pisgah NFs based on the 2005 Lidar data.

The model steps identified below are developed in Model Builder, and saved in the toolbox called "GapAnalysis_NP.tbx" located here T:\FS\NFS\NFinNorthCarolina\Project\SO\2013Revision\GIS\wildlife\GapAnalysis.

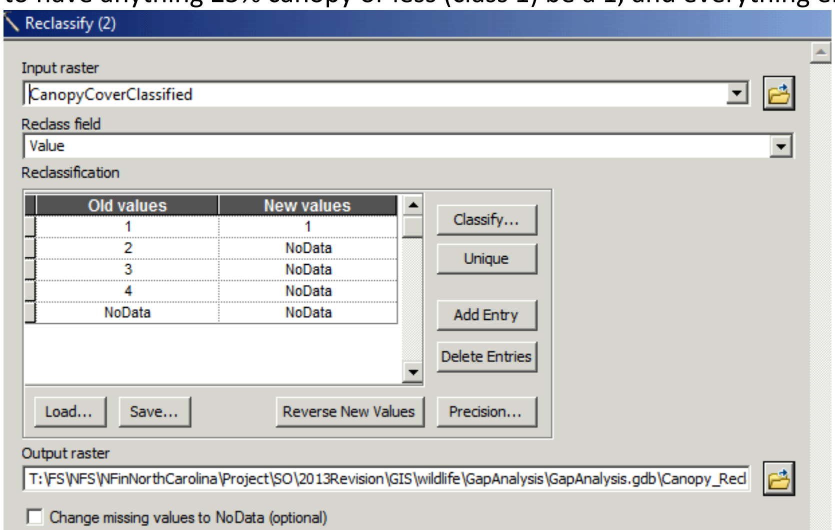
The ArcMap project that includes all of the gap analysis data is called "GapAnalysis.mxd" and is saved here T:\FS\NFS\NFinNorthCarolina\Project\SO\2013Revision\GIS\wildlife\GapAnalysis.

The geodatabases that contain the gap analysis layers is called

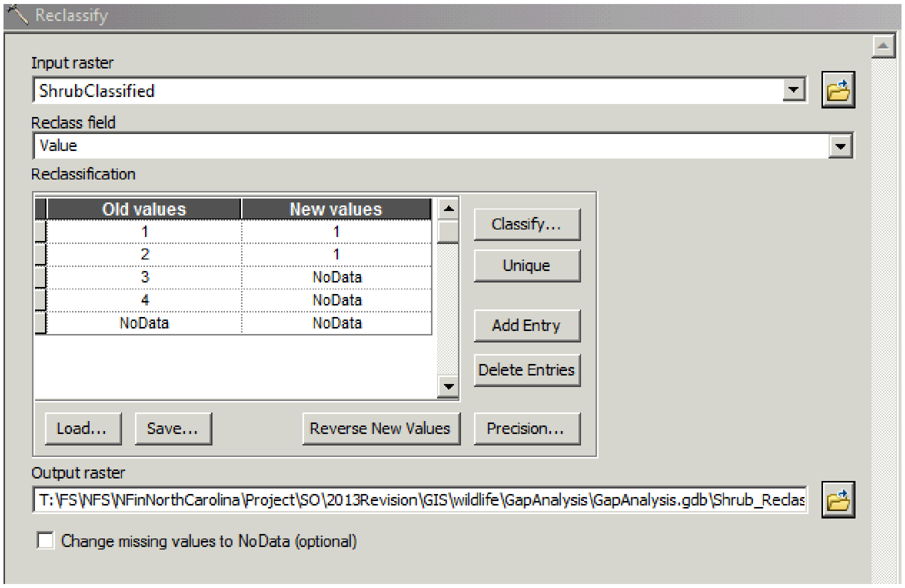
## STEP 1: Classify vegetation datasets to select the attributes we want.

We're defining gaps as anything having Canopy Cover ≤25% AND Canopy Height ≤15' AND Shrub Density ≤50%.  Here's how to do that

1. "Canopy Cover Phase 3 Classified" raster (from Mark E's data) , add field 'reclass' and reclassified to have anything 25% canopy or less (class 1) be a 1, and everything else "nodata"




2. "Canopy Height Classified" raster , add field 'reclass' and reclassified to have anything 15' height or less (class 1, 2, 3) be a 1, and everything else "nodata"
3. "Shrub Cover Classified" raster , add field 'reclass' and reclassified to have anything 50% canopy or less (value=1 or 2) be a 1,  everything else "nodata"

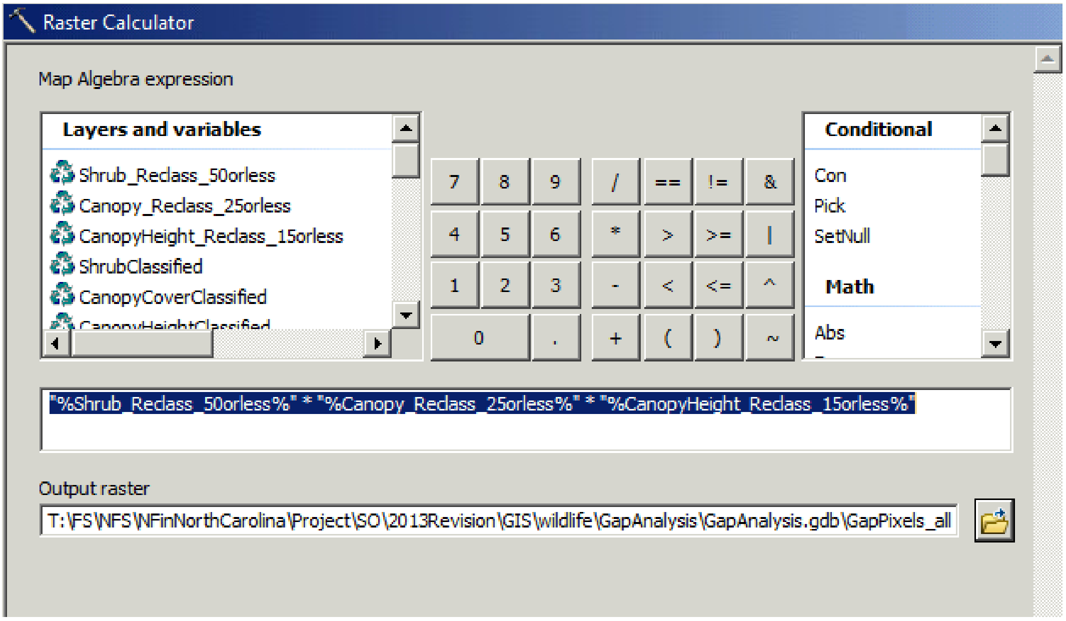



4. Also while reclassifying the base datasets, we went ahead and reclassified the Ecozones ("Ecozones_lumped_rs" from Mark E's original data) to have the following values (this comes in handy down in Step 5):

| | |
|---|---|
| 100 | Spruce-fir |
| 200 | Northern Hardwood Slope |
| 300 | High Elevation Red Oak |
| 400 | Acidic Cove |
| 500 | Rich Cove |
| 600 | Montane Oak-Hickory Slope |
| 700 | Dry Mesic Oak |
| 800 | Dry Oak Evergreen and Deciduous Heath |
| 900 | Pine-Oak Heath |
| 1000 | Low Elevation Pine Shrub |
| 1100 | Montane Alluvial and Large Floodplain |
| 1200 | Grassy Bald |
| 1300 | Health Bald |
| 1400 | Reservoirs and Lakes and Ponds |

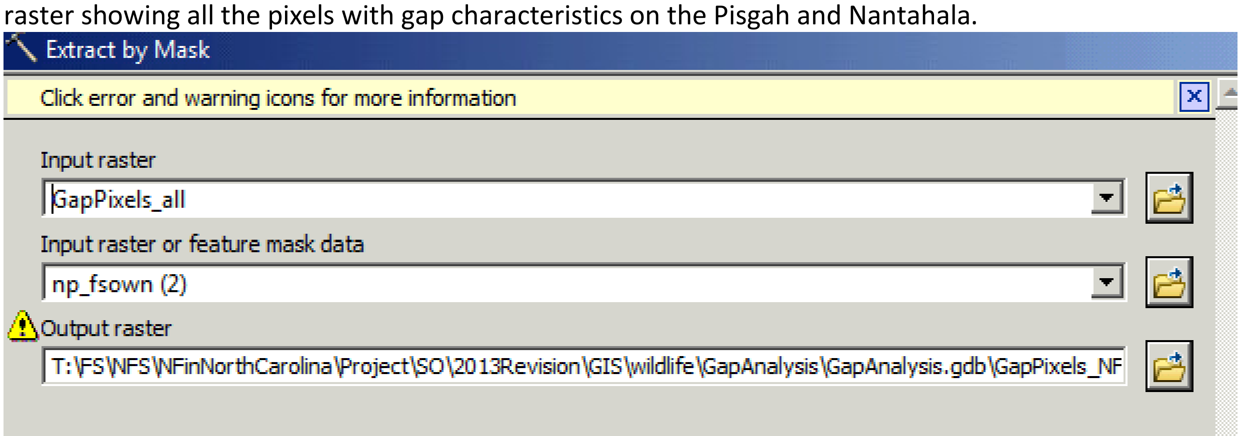
## STEP 2: Create a new raster that combined height, canopy cover, and shrub density to identify every pixel on the landscape that has characteristics of a gap.

To do that, I combined these three layers using Raster Calculator, which multiplied the values together so that all gaps received a value of either 1 or NoData.  This output is called "GapPixels_all"




## Step 3: Clipped the gap pixels to NFS lands.

Used "Extract By Mask" command to do this (can use a polygon to clip a raster!)  So the result was a raster showing all the pixels with gap characteristics on the Pisgah and Nantahala.

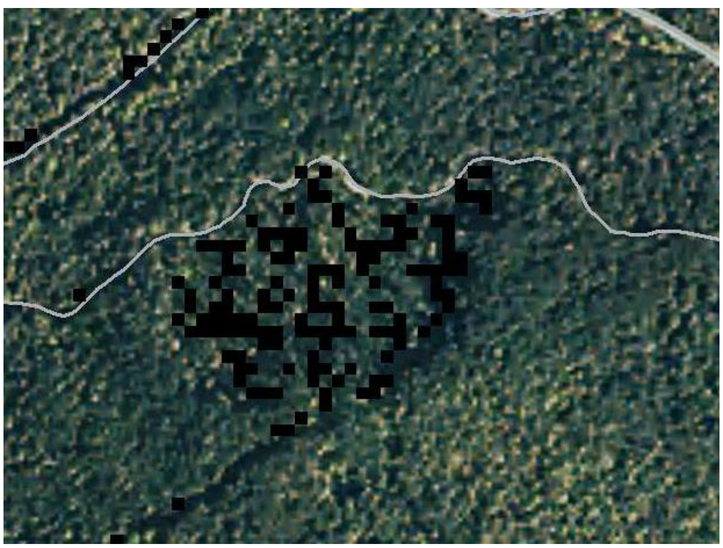



## Step 4: Aggregate the gap pixels to allow for better identification of ecologically functional patches.

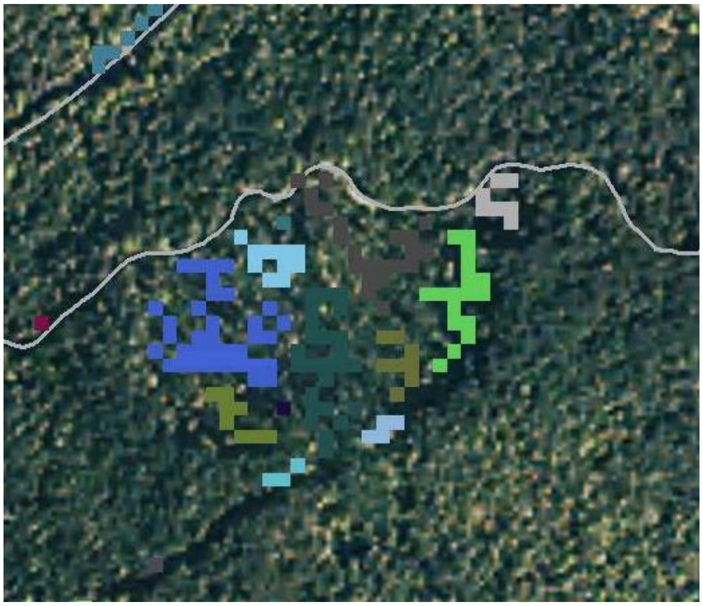
This step got added in after we looked at what happened without it, and saw that there were a lot of patches being identified as separate, that really functionally were all one patch.  For example:

Look at this sample area-- a harvest unit that looks like one unit.

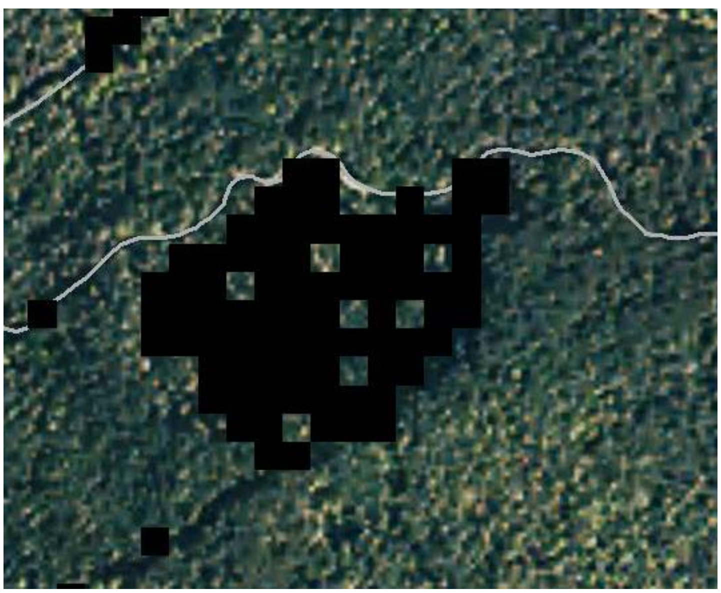
Our first cut at identifying gap pixels showed us the reality, which is that there is some variation in the unit:



But under this scenario, when we identify patches, this would result in several different patches, broken apart where pixels aren't touching one another (each color below is a separate patch).

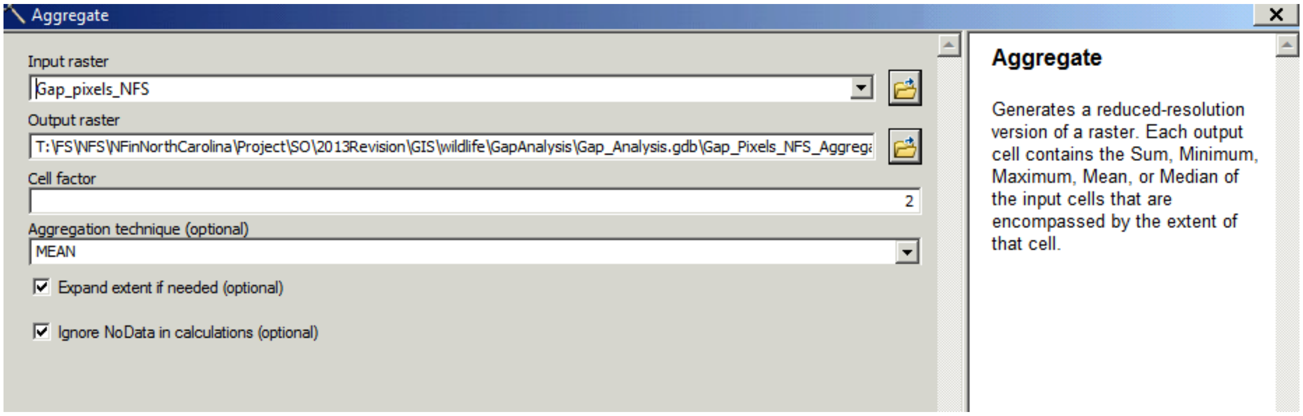


By using the aggregate tool, we were able to reduce the resolution of the pixels by a factor of 2, and then look to see if the majority of new pixel was previously identified as a gap or not.  If so, the new pixel was considered gap, and if not, it wasn't.

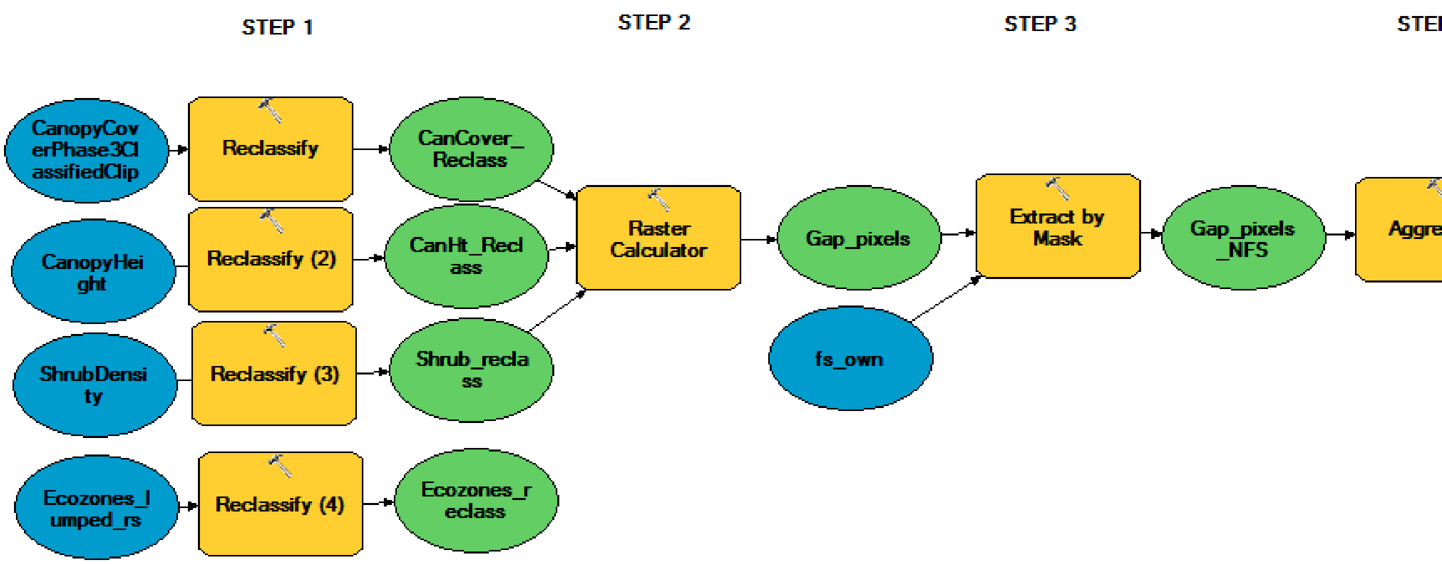


Now this big blob will show up as one large patch in step 5 below, and will allow for more meaningful ecological identification of the gap patches.

The following shows the model input to perform the aggregation.  The cell factor of 2 changes our pixel size from a 40'x40' pixel to an 80'x80' pixel.

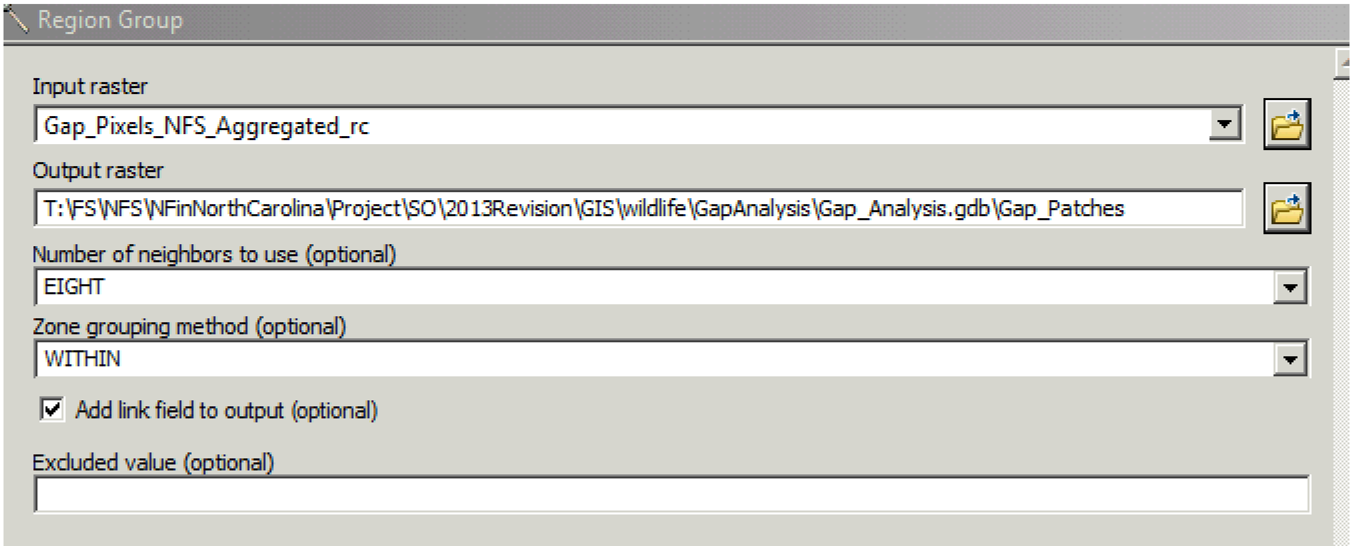



Steps 1-4 are represented in the following model (called "Step_1_2_3_4" in GapAnalysis_NP.tbx (Toolbox) located here: T:\FS\NFS\NFinNorthCarolina\Project\SO\2013Revision\GIS\wildlife\GapAnalysis)



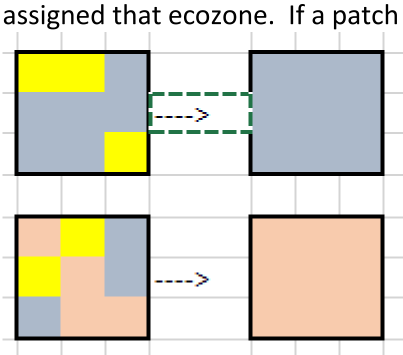

## Step 5: Identify patches from the pixels.

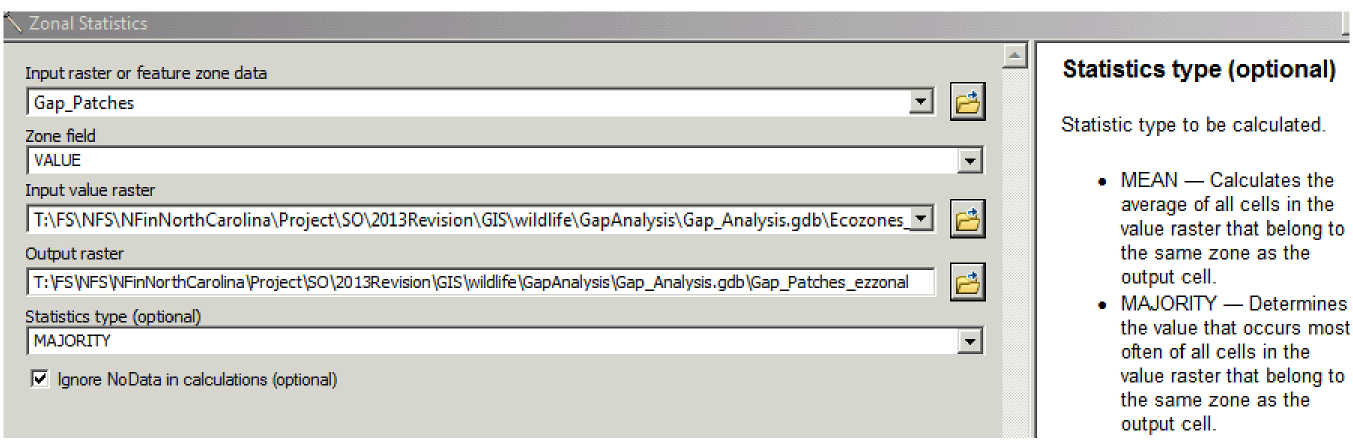
Group all gap pixels together into patches, based on whether they were touching on at least one side or corner



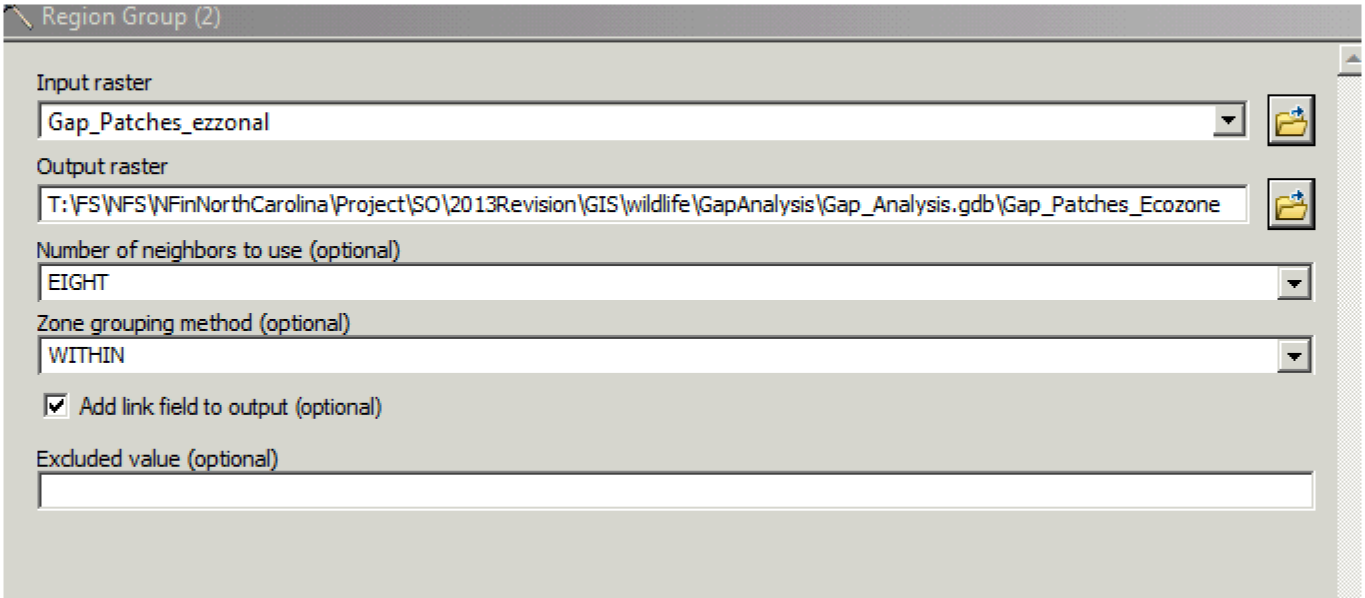

## Step 6: Identify which ecozone the patch is primarily in.

Then we had to break out patches based on what ecozone the majority of pixels in that patch were. To do this, we used a tool called "Zonal Statistics." This step used the Gap Patches that we created in Step 5, and looked to see which Ecozone(s) those patches were in. If a patch was all in one ecozone, it was assigned that ecozone. If a patch overlapped two or more ecozones, we chose the MAJORITY ecozone.

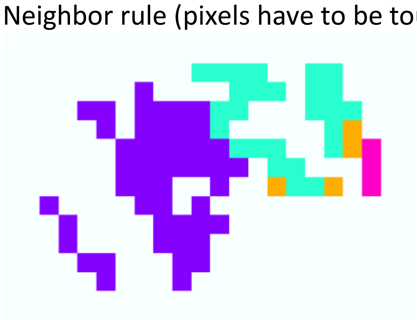


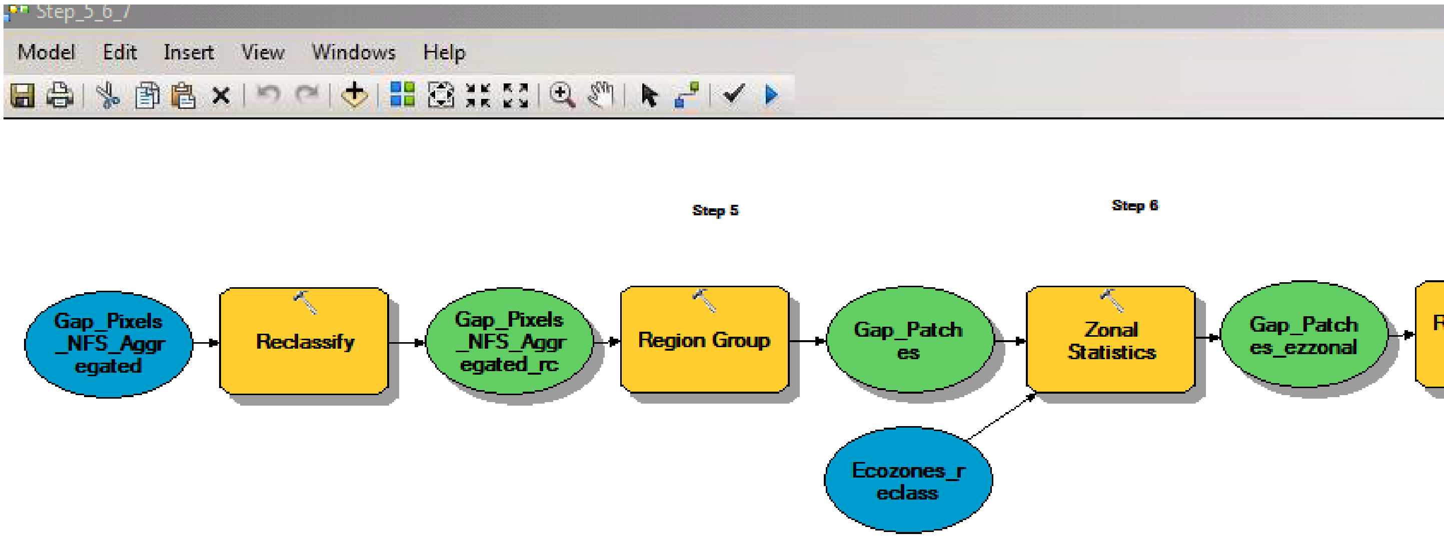
## Step 7: Group patches of similar ecozone together as one.




Example: This shows multiple ecozones within the same patch (above), which were aggregated into patches based on the majority ecozone. Three patches total were created, based on the Eight Neighbor rule (pixels have to be touching on a side or corner to be considered the same patch).

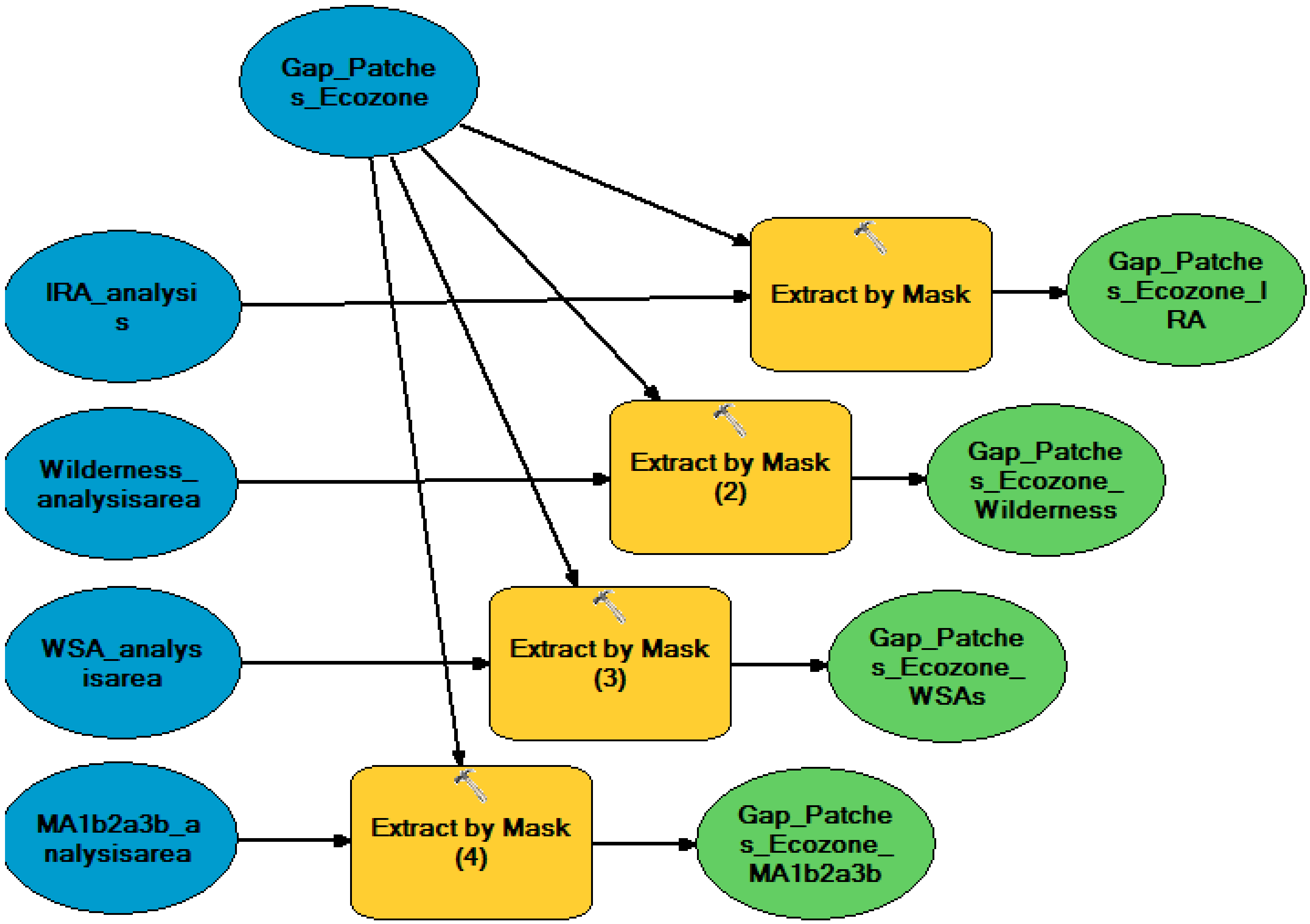


The model for steps 5-7 looks like this and is saved in the same toolbox referenced above.




## Step 9-- Clip the gap patches to different management areas (wilderness, WSAs, IRAs, MA1 only, and MA 1-3).

After doing this, export all the attribute tables to .dbf files, then open in Excel to start calculating totals, frequency, etc




## STEP 9. Calculated Acres, Exported to Excel for further analysis.

Opened the attribute tables and added a column called "Acres" (which the type was 'float') and then right-clicked to do a Field Calculator where Acres= Count * (6400/42560). Rationale for this equation:

Which is derived from the cell size (80'x80' or 6400 sq ft) divided by the square feet in an acre (43560 sq ft).

Acres= xx pixels x 80’x80’ (6400 sq ft)/pixel x 1 ac/42,560 sq ft

STEP 10. Convert to Polygon

** Need help figuring out how to do this, because when I do, it creates more polygons than I want, splitting out anything that's touching on a corner, whereas the raster will keep those together as a patch.

# ESH Analysis

Thursday, March 17, 2016    12:45 PM

## STEP 1: Classify vegetation datasets to select the attributes we want.

We're defining ESH in two classes:

ESH Moderate= Tree Height <15' and Canopy 25-60%

ESH Dense= Tree Height <15' and Canopy 60%+

1. "Canopy Cover Phase 3 Classified" raster (from Mark E's data) , add field 'reclass' and reclassified to have anything 25-60% canopy be a 1, 60-100% is a 2, and <25% is a "No Data"

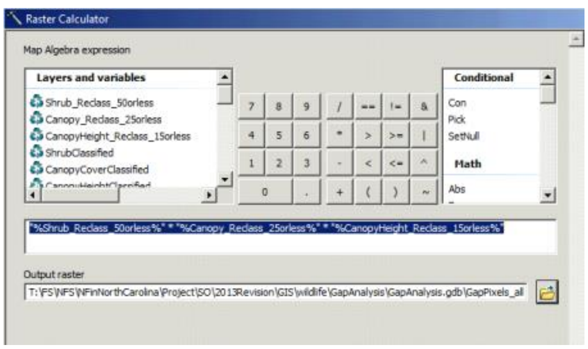
2. "Canopy Height " raster , add field 'reclass' and reclassified to have anything 15' height or less be a 1, and everything else "nodata"

3. Also while reclassifying the base datasets, we went ahead and reclassified the Ecozones ("Ecozones_lumped_rs" from Mark E's original data) to have the following values (this comes in handy down in Step 5):

| | |
|---|---|
| 100 | Spruce-fir |
| 200 | Northern Hardwood Slope |
| 300 | High Elevation Red Oak |
| 400 | Acidic Cove |
| 500 | Rich Cove |
| 600 | Montane Oak-Hickory Slope |
| 700 | Dry Mesic Oak |
| 800 | Dry Oak Evergreen and Deciduous Heath |
| 900 | Pine-Oak Heath |
| 1000 | Low Elevation Pine Shrub |
| 1100 | Montane Alluvial and Large Floodplain |
| 1200 | Grassy Bald |
| 1300 | Health Bald |
| 1400 | Reservoirs and Lakes and Ponds |

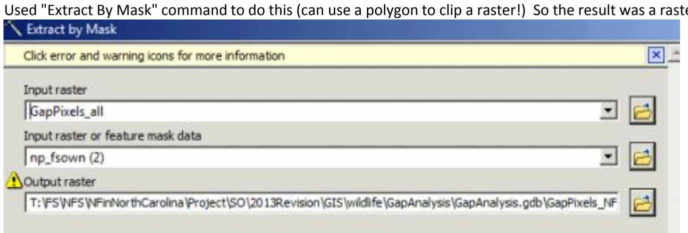
## STEP 2: Create a new raster that combined height & canopy cover to identify every pixel on the landscape that has characteristics of ESH.

To do that, I combined the layers using Raster Calculator, which multiplied the values together so that all gaps received a value of either 1,2 or NoData. This output is called "esh_pixels"




## Step 3: Clipped the gap pixels to NFS lands.

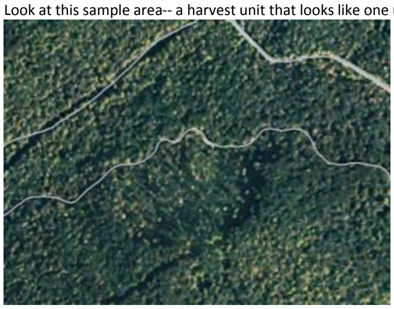
Used "Extract By Mask" command to do this (can use a polygon to clip a raster!) So the result was a raster showing all the pixels with gap characteristics on the Pisgah and Nantahala.



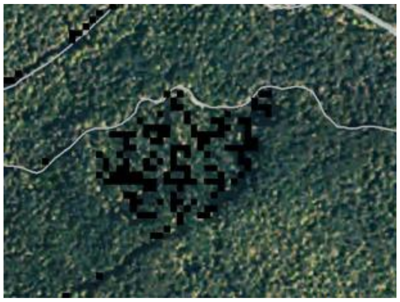

## Step 4: Aggregate the gap pixels to allow for better identification of ecologically functional patches.

This step got added in after we looked at what happened without it, and saw that there were a lot of patches being idetnified as separate, that really functionally were all one patch. For example:

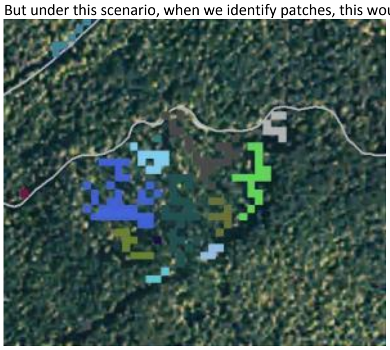
Look at this sample area-- a harvest unit that looks like one unit.



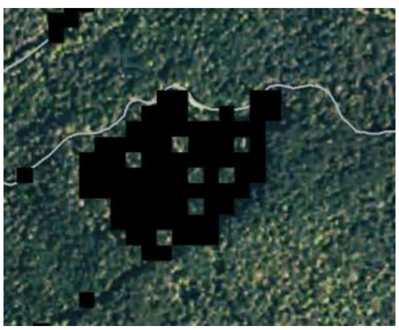
Our first cut at identifying gap pixels showed us the reality, which is that there is some variation in the unit:



But under this scenario, when we identify patches, this would result in several different patches, broken apart where pixelsaren't touching one another (each color below is a separate patch).

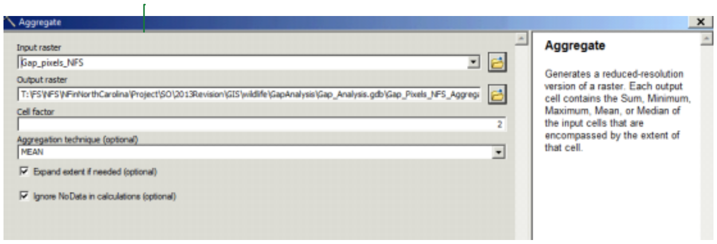


By using the aggregate tool, we were able to reduce the resolution of the pixels by a factor of 2, and then look to see if the majority of new pixel was previously identified as a gap or not. If so, the new pixel was considered gap, and if not, it wasn't.

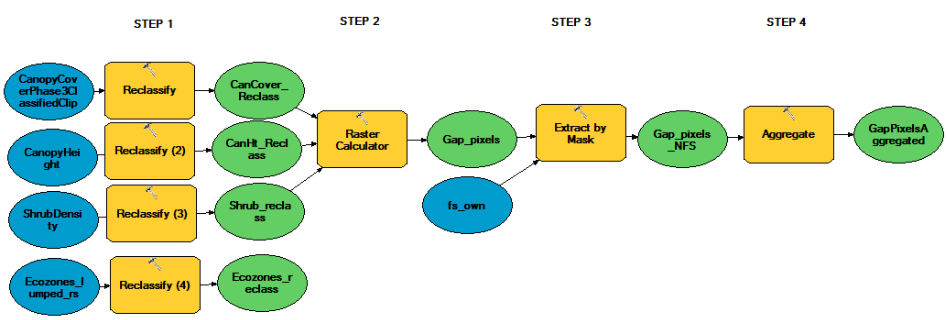


Now this big blob will show up as one large patch in step 5 below, and will allow for more meaningful ecological identification of the gap patches.

The following shows the model input to perform the aggregation. The cell factor of 2 changes our pixel size from a 40'x40' pixel to an 80'x80' pixel.

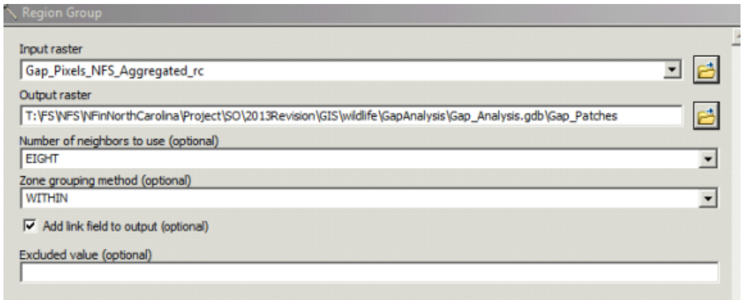



Steps 1-4 are represented in the following model (called "Step_1_2_3_4" in ESH_Analysis.tbx (Toolbox) located here: T:\FS\NFS\NFinNorthCarolina\Project\SO\2013Revision\GIS\wildlife\GapAnalysis)



## Step 5: Identify patches from the pixels.

Group all gap pixels together into patches, based on whether they were touching on at least one side or corner

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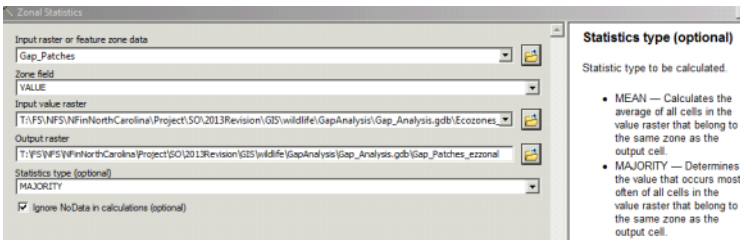
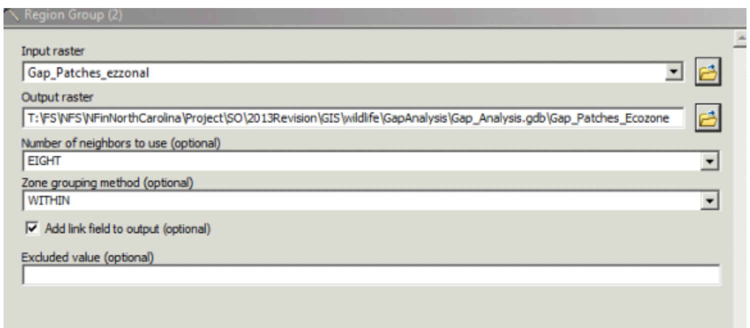



## Step 7: Group patches of similar ecozone together as one.

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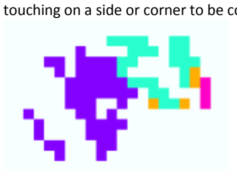
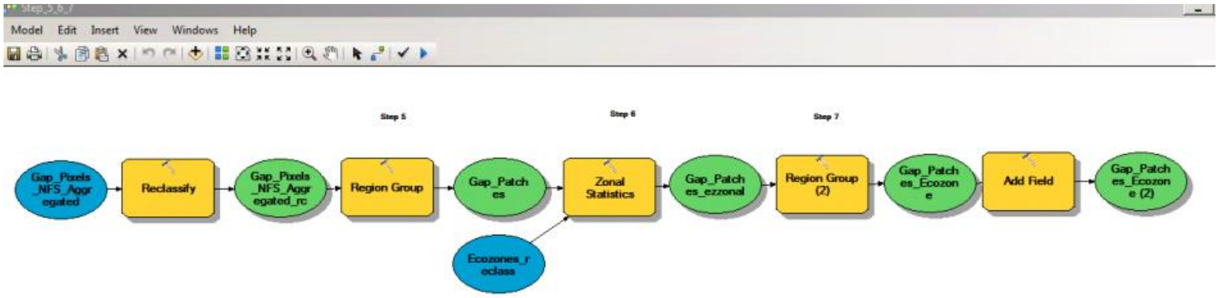


The model for steps 5-7 looks like this and is saved in the same toolbox referenced above.




### Step 9-- Clip the gap patches to different management areas (wilderness, WSAs, IRAs, MA1 only, and MA 1-3).

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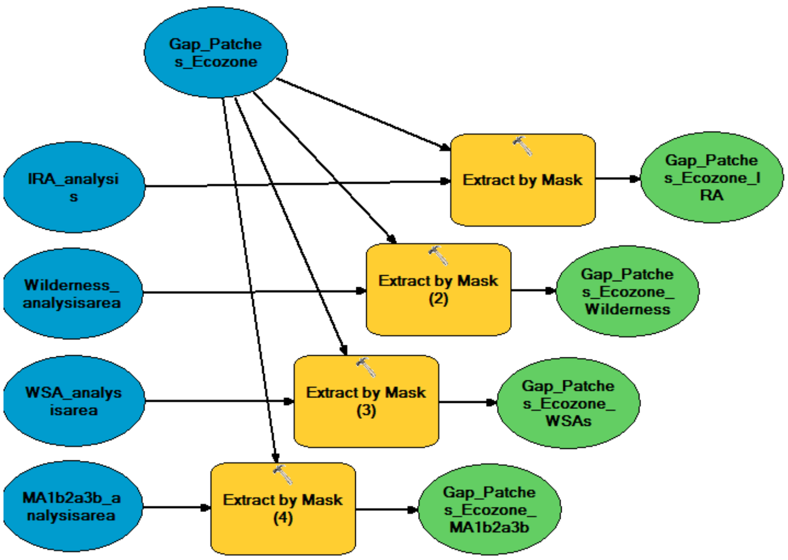


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Which is derived from the cell size (80'x80' or 6400 sq ft) divided by the square feet in an acre (43560 sq ft).

Acres= xx pixels x 80'x80' (6400 sq ft)/pixel x 1 ac/42,560 sq ft

Results

A total of 30

# Attachment 02

Procedure for Estimating the Natural Range of Variation (NRV)
Nantahala and Pisgah National Forests – January 2015

***National Forests in North Carolina***
***Procedure for Estimating the Natural Range of Variation (NRV)***
***Nantahala and Pisgah National Forests***
***January 2015***

## NRV Steps

**Completed with Kori Blankenship, Landfire TNC Ecologist**

1) **Define an appropriate geographic area** - We included a size large enough to incorporate the 18 county area surrounding the Nantahala and Pisgah NFs. The size was large enough to be statistically significant based on the accuracy of the data for the disturbance frequencies.

2) **Determine appropriate ecozones -** Table 1 identifies the 11 modeled ecological zones that include the majority of the lands across the Nantahala and Pisgah National Forests. Ecological Zones are defined as units of land that can support a specific plant community or plant community group based upon environmental factors such as temperature, moisture, fertility, and solar radiation that control vegetation distribution (Simon 2011). Based on the modeling completed for these types we met with the botanists and silviculturists from the mountain ranger districts, the southern research station, and state land management agencies and merged types with similar plant diversity, such as acidic cove and oak-rhododendron types, and/or overstory, such as northern hardwood cove or northern hardwood slope.

Table 1. Eleven Ecological Zones across Nantahala and Pisgah NFs derived by combining similar ecological types.

| EcoZones | Changes | Nantahala and Pisgah Acres | Forest % |
|---|---|---|---|
| Spruce-Fir | Spruce-Fir | 16604 | 2% |
| Northern Hardwood Slope, Northern Hardwood Cove | Northern Hardwood | 53924 | 5% |
| High Elevation Red Oak | High Elevation Red Oak | 38637 | 4% |
| Acidic Cove, Mixed Oak-Rhododendron | Acidic Cove | 240938 | 23% |
| Rich Cove | Rich Cove | 189143 | 18% |
| Mesic Oak Slope, Mesic Oak Cove | Mesic Oak | 186131 | 18% |
| Dry-Mesic Oak Forest | Dry-Mesic Oak | 105991 | 10% |
| Dry Oak Evergreen, Dry Oak Deciduous | Dry Oak | 59677 | 6% |
| Pine-Oak/Heath | Pine-Oak/Heath | 101275 | 10% |
| Low Elevation Pine, Low Elevation Pine-Oak | Shortleaf Pine-Oak | 44451 | 4% |
| Alluvial, Large Floodplain | Alluvial | 2640 | 0.3% |

3) To the extent possible we also examined any correlation with FSVeg types to examine for existing condition. The majority did not have a 1:1 match and typically were incorporated in multiple ecozones. Potentially only the red oak type, ev code 55, closely matched the type. And this type only occurred in 17% of the modeled high elevation red oak forest type. Most FSVeg forest types occurred in mid elevation forests. The same pattern was seen for other FSVeg types and typically occurred across multiple ecozones.

Table 2. Correlation or lack of between Ecozones and FSVeg types.

| **Ecozones** | **Forest Type - FSVeg Code** |
|---|---|
| Spruce-Fir | 6, 7, 10, 17 |
| Northern Hardwood | 70, 81 |
| High Elevation Red Oak | 55 |
| Acidic Cove | 4, 5, 8, 9, 41, 50, 56, 83 |
| Rich Cove | 9, 41, 50, 56, 82, 83 |
| Mesic Oak | 10, 42, 48, 53, 54 |
| Dry-Mesic Oak | 3, 42, 48, 52, 53, 54 |
| Dry Oak | 42, 51, 52, 54, 57, 59, 60 |
| Pine-Oak/Heath | 15, 16, 20, 25, 33, 38, 49 |
| Shortleaf Pine-Oak | 3, 12, 13, 14, 16, 21, 25, 31, 32, 33, 44, 49 |
| Alluvial | 72, 82 |

4) LANDFIRE (landfire.org) is a nationally created database that in part describes the vegetation dynamics, including structure and disturbance regimes for more than 1,000 ecosystems, called Biophysical Setting (BpS), in the United States (Rollins 2009). Biophysical Settings represents vegetation that may have been dominant on the landscape prior to Euro-American settlement and are based on both the current biophysical environment and an approximation of the historical disturbance regime. Biophysical Settings (BpS) represents vegetation that may have been dominant on the landscape prior to Euro-American settlement and are based on both the current biophysical environment and an approximation of the historical disturbance regime. Map units are defined by Nature Serve (NatureServe.org) Ecological Systems, a nationally consistent set of mid-scale ecological units. BpSs are intended to be dynamic and can be updated with more accurate information, such as disturbance regime frequencies. Potentially new ones can be created for regional variation. In December of 2014 we examined the existing BpS models correlating them with the 11 ecozones to the extent possible. Two ecozones, acidic and rich cove, although quite different in species composition, are quite similar in disturbance regimes and topographic setting. As a result they were correlated as a single unit.

Table 3. Correlation between Ecozones and LANDFIRE Biophysical Setting.

| EcoZone | BpS Name | BpS Code |
|---|---|---|
| Dry-Mesic Oak | Southern Appalachian Oak Forest | 5713150 |
| Dry Oak | Allegheny-Cumberland Dry Oak Forest And Woodland | 5713170 |
| Mesic Oak | Montane Red Oak - Chestnut Oak | new provisional (Simon & Croy) |
| Rich and Acidic Cove | Southern and Central Appalachian Cove Forest | 5713180 |
| Pine-Oak/Heath | Southern Appalachian Montane Pine Forest and Woodland | 5713520 |
| Shortleaf Pine-Oak | Southern Appalachian Low-Elevation Pine Forest | 5713530 |
| Floodplain Forest | Central Interior and Appalachian Floodplain Systems | 5714710 |
| Spruce-Fir | Central and Southern Appalachian Spruce-Fir Forest | 5713500 |
| Northern Hardwood | Southern Appalachian Northern Hardwood Forest | 5713090 |
| High Elevation Red Oak | Central and Southern Appalachian Montane Oak Forest | 5713200 |

5) Natural range of variation represents the percent of different succession (s) classes that is found under natural ecological processes with natural disturbance regimes. S-Classes represent differences in age and structure, open vs. closed. An open structure was assumed to represent 40-80% canopy cover and would allow for greater grass and herb diversity, particularly in fire adapted ecozones. It is assumed the drier fire-adapted types, pine-oak/heath, shortleaf-pine, and dry oak, have a lower average woodland canopy, ranging from 40-60%, than dry-mesic oak, which would range from 50-70%, and mesic oak and high elevation red oak, with a range from 60-80%. BpS models typically develop a 5 class system from young (early seral) forest, mid-age open forest, mid-age closed forest, old-age open forest, and old-age closed forest. BpS model variations on the number of s-classes variations have been developed, included the southern Appalachians. We examined three local variations within other southern Appalachian reviews of the BpS models. These included a review of a subset of the southern Appalachian models in Asheville by regional experts in 2012, a variation developed for the north zone of the Cherokee NF, and a local variation developed for the Warwoman watershed on the Chattahoochee NF. Both the later variations included an old growth class that developed seven s-Classes versus five s-Classes. We incorporated the old growth s-class developing our variation for western North Carolina based on the best examples of the three modeling efforts and by detecting inconsistencies across age classes. We were surprised at the lack of young forest when there was so much difference in old growth percentages (Late2 in Table 4). Our goal was to review the systems and learn from previous modeling efforts creating less discrepancies when examining all ten BpS models relative to each other. As a result of detecting differences for the same s-Classes within the same BpS we determined it would be desirable wanted to develop a range for all the S-Classes versus a single fixed percentage.

Table 4. Variation between s-Classes between BpS models across the Southern Appalachians. Chatt = Warwoman watershed on Chattahoochee NF, Cher = North Zone Cherokee NF, Sapp = Southern Appalachian subset. Numbers represent percent of individual ecozone.

| Types | Mesic Oak | | | | Dry Mesic Oak | | | | Dry Oak | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| S-Classes | Chatt | Cher | Sapp | | Chatt | Cher | Sapp | | Chatt | Cher | Sapp |
| Early | 5 | 7 | 5 | | 7 | 7 | 6 | | 7 | 10 | 6 |
| Mid -Closed | 8 | 26 | 6 | | 6 | 15 | 10 | | 4 | 15 | 4 |
| Mid-Open | 7 | 20 | 7 | | 13 | 25 | 10 | | 13 | 31 | 13 |
| Late- Open | 6 | 12 | 6 | | 14 | 23 | 14 | | 18 | 15 | 18 |
| Late-Closed | 5 | 18 | 5 | | 5 | 13 | 5 | | 3 | 8 | 3 |
| Late2- Open | 38 | 2 | 39 | | 42 | 11 | 49 | | 57 | 7 | 57 |
| Late2- Closed | 31 | 14 | 31 | | 12 | 6 | 6 | | 1 | 14 | 1 |
| **Total Closed** | **44** | **58** | **42** | | **23** | **34** | **21** | | **8** | **37** | **8** |
| **Total Open/Early** | **56** | **41** | **57** | | **76** | **66** | **79** | | **95** | **63** | **94** |

6) To begin the modeling process we developed age and successional classes for each of the 11 ecozones for the Nantahala/Pisgah, which will be represented by 10 BpS models. The early class was determined by silvicultural conditions in particular the growth rate of the major dominate tree species, the density of tree species resulting in canopy closure, and the change in shrub, grass and herbaceous species dominance (Table 5). Mid ages were assumed to be longer in more mesic systems (cove and floodplain forests) and less within xeric ecozones (dry oak and pine-oak/heath). For the majority of the maximum ages for the late age class and the beginning of the old growth class were based on the region 8 guidelines for old growth (1997). An exception is for dry-mesic oak forest, pine-oak heath forest, northern hardwood forest and floodplain forest. For each of those types the minimum old growth age was increased to 130 years for the first three and 140 years for the later (Table 5).

Table 5. Ages of s-Classes for the ten BpS models developed for the Nantahala and Pisgah National Forests.

| Ecozones | Age Class | | | |
|---|---|---|---|---|
| | Early | Mid | Late | Old Growth |
| Spruce-Fir | 0-35 | 36-70 | 71-120 | 120+ |
| High Elevation Red Oak | 0-20 | 21-70 | 71-130 | 130+ |
| Northern Hardwood | 0-15 | 16-75 | 76-130 | 130+ |
| Cove (Rich or Acidic) | 0-10 | 11-100 | 101-140 | 140+ |
| Mesic Oak | 0-10 | 11-80 | 81-130 | 130+ |
| Dry-Mesic Oak | 0-15 | 16-75 | 76-130 | 130+ |
| Dry Oak | 0-20 | 21-70 | 71-100 | 100+ |
| Pine-Oak heath | 0-20 | 21-70 | 71-130 | 130+ |
| Low Elevation pine | 0-15 | 16-70 | 71-100 | 100+ |
| Floodplain | 0-10 | 11-100 | 101-140 | 140+ |

7) We determined the appropriate disturbance regimes (type and frequency) for each separate BpS model (Table 6). There is uncertainty on frequencies for many disturbance types given the lack of historical data. The analysis was completed on a relative scale of intensity and frequency of any disturbance when comparing all 11 ecozones. For instance, it was assumed the frequency and intensity of wind and weather events was greater on an exposed landscape, where dry oak or pine-oak heath ecozones are present, in comparison to more protected concave landscape features, typically where rich cove, acidic cove or northern hardwood ecozones occur. We initially separated more disturbance events, such as ice storms from wind events, but after running models, it did not make any appreciable difference in the outcomes. Based on Kori Blankenship's, Landfire TNC modeler, previous experience with other landscape NRV modeling we simplified the number of disturbances.

Table 6. Frequency (years) of separate disturbance classes for the ten BpS models developed for the Nantahala and Pisgah National Forests.

| Disturbances | POH | SLP | Dry Oak | Dry-Mesic Oak | Mesic Oak | HERO | SF | NHwd | Cove | Flood |
|---|---|---|---|---|---|---|---|---|---|---|
| Min Surface Fire | 3 | 2 | 5 | 14 | 18 | 11 | | 100 | 50 | 50 |
| Max Surface Fire | 15 | 12 | 20 | 20 | 25 | 20 | | 500 | 250 | 350 |
| Average Surface Fire | 5 | 5 | 10 | 15 | 20 | 15 | | 333 | 100 | 200 |
| | | | | | | | | | | |
| Min Mixed Fire | 20 | 20 | 25 | 80 | 80 | 50 | 600 | 500 | 400 | 400 |
| Max Mixed Fire | 100 | 100 | 100 | 250 | 250 | 100 | 2000 | 1000 | 1000 | 1000 |
| Average Mixed Fire | 50 | 50 | 60 | 100 | 100 | 70 | 1000 | 602 | 500 | 500 |
| | | | | | | | | | | |
| Min Replacement Fire | 30 | 30 | 25 | 200 | 100 | 100 | 600 | 500 | 500 | 200 |
| Max Replacement Fire | 300 | 500 | 500 | 500 | 500 | 500 | 2000 | 1000 | 1500 | 1000 |
| Average Replacement Fire | 150 | 200 | 250 | 300 | 350 | 350 | 1000 | 602 | 1000 | 612 |
| | | | | | | | | | | |
| Min Wind/Weather | 100 | 100 | 70 | 150 | 150 | 40 | 100 | 120 | 200 | 120 |
| Max Wind/Weather | 300 | 333 | 333 | 400 | 400 | 300 | 333 | 500 | 500 | 250 |
| Average Wind/Weather | 150 | 150 | 100 | 200 | 250 | 100 | 150 | 200 | 300 | 150 |
| | | | | | | | | | | |
| Min Extreme Wind/Ice | 100 | | | | | 80 | | 100 | 100 | |
| Max Extreme Wind/Ice | 300 | | | | | 400 | | 500 | 700 | |
| Average Extreme Wind/Ice | 250 | | | | | 250 | | 333 | 500 | |
| | | | | | | | | | | |
| Min Insect/Disease | 60 | 70 | 70 | 100 | 100 | 70 | 50 | 80 | 100 | 100 |
| Max Insect/Disease | 200 | 200 | 200 | 400 | 400 | 300 | 333 | 350 | 400 | 400 |
| Average Insect/Disease | 100 | 125 | 125 | 200 | 250 | 125 | 100 | 200 | 250 | 250 |
| | | | | | | | | | | |
| Min Flooding | | | | | | | | | | 50 |
| Max Flooding | | | | | | | | | | 400 |
| Average Flooding | | | | | | | | | | 120 |
| | | | | | | | | | | |

8) To develop s-Class average means, we used state-and-transition modeling ST-Sim software (Apex Resource Management Solutions), which assigns probabilities to the transitions and stochastically simulates multiple iterations of the model. For each BpS model we simulated for a 1000-year period with separate iterations. In order to determine how many iterations would be sufficient before normalization we ran half the models for 300 iterations. However, when there was a negligible difference with the results it was assumed 100 iterations would suffice to derive s-Class separations. For nine models we derived seven s-Classes based on age and open or closed criteria. For cove forest, representing both acidic cove and rich cove ecozones, we only derived a closed old growth s-Class. This is based on our assumption these are the most protected ecozones in the landscape and would not have an open condition.

9) In order to derive ranges for each s-Class we examined the probability distributions around each average. ST-SIM can be used with either a normal or a beta distribution. We selected beta distribution since one can tie it to a minimum and maximum for disturbances. By using a standard deviation of the beta distribution for each disturbance type it is possible to approximate a bell-shaped curve. The bell-shaped curve was visually optimized examining changes in the frequency distribution shape while maintaining the widest possible frequency vales, from which minimum and maximum multipliers were derived. These multipliers were used to provide a range for individual s-Classes for each ecozone.

Figure 1. Bell-shaped curve for surface fires for Pine-Oak/Heath ecozone.

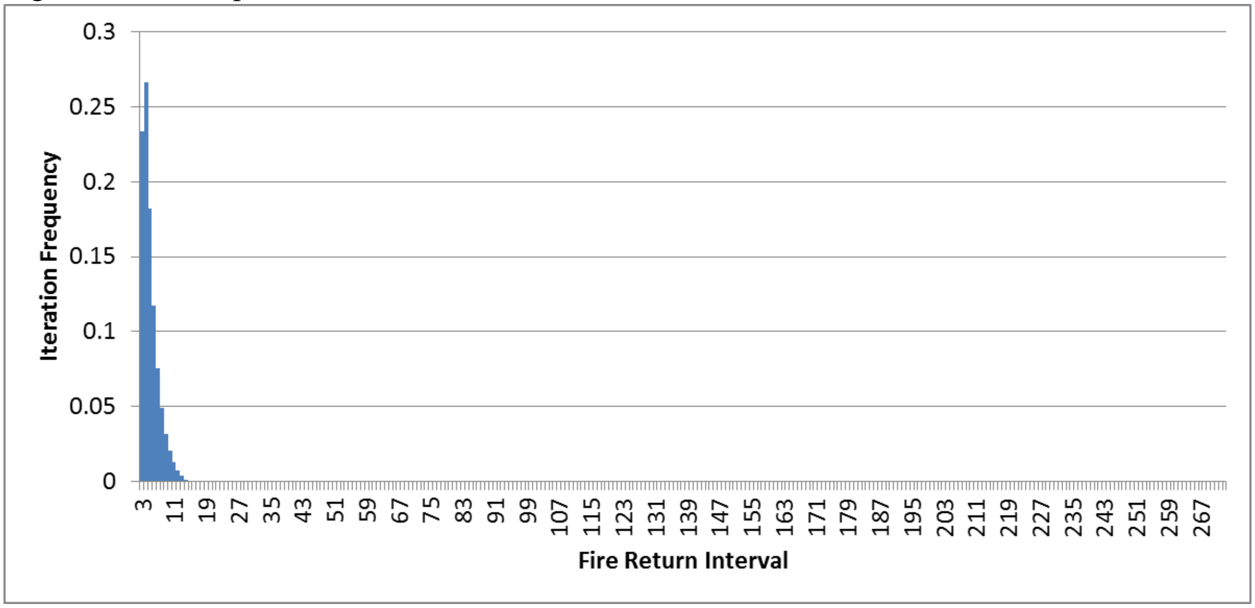



Figure 2. Bell-shaped curve for wind frequencies for Pine-Oak/Heath ecozone.

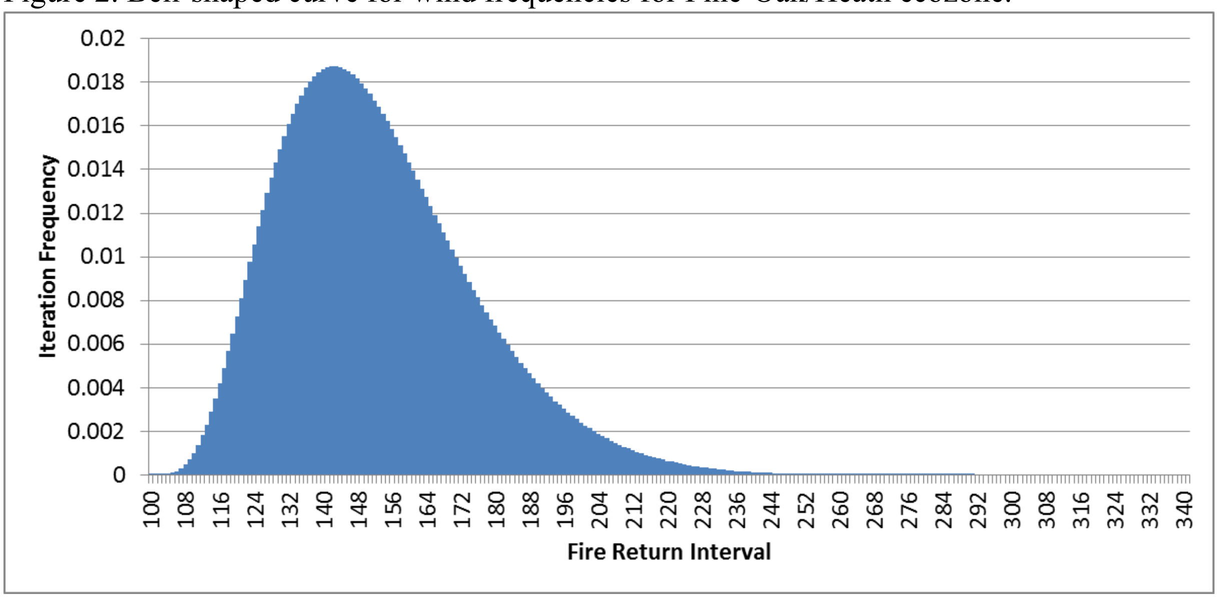
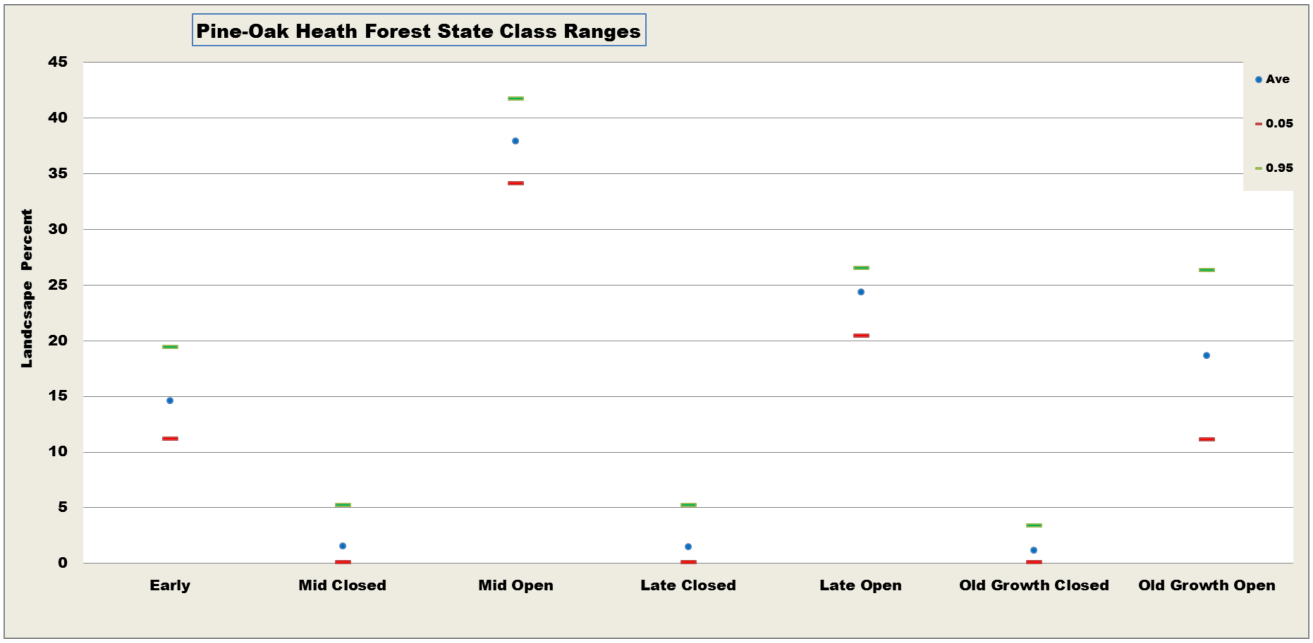


Figure 3. Results of NRV simulations with final ranges within each s-Class for Pine-Oak/Heath ecozone.

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# Attachment 03

Probability NRV Models for Nantahala and Pisgah NFs Plan Revision – June 2020

## Probability NRV Models for Nantahala and Pisgah NFs Plan Revision

## June 2020, prepared by Gary Kauffman

Included in separate spreadsheets are the probabilistic calculations for the separate state classes by ecozone. The following guide provides info on the data:

1) First Column with the vegetation type is the ecozone. Both acidic and rich coves have the same disturbance patterns so are treated together
2) State classes acronyms represent the following:
- Early1:All = Young Forest
- Mid1:CLS = Mid aged closed canopy forest
- Mid1:OPN = Mid aged open canopy forest
- Late1:CLS = Old aged closed canopy forest
- Late1:OPN = Old aged open canopy forest
- Late2:CLS = Old Growth closed canopy forest
- Late2:OPN = Old Growth open canopy forest
3) The Transition Type is the Disturbance type. Optional is a catchall for multiple disturbances.
4) Prob is the probability is the likelihood of occurrence for the disturbance. A probability of 0 essentially represents an impossibility while 1 a certainty. Thus, a probability of .002 occurs .2% of the time while .01 is at a 10% frequency.
5) The Age Reset indicates if the disturbance results in the state class moving to young forest.

| From Vegetation Type | From Class | To Class | Transition Type | Prob | Propn | Age Reset | TST Min |
|---|---|---|---|---|---|---|---|
| SpruceFir | Early1:ALL | Early1:ALL | ReplacementFire | 0.0010 | 1.0000 | Yes | |
| SpruceFir | Late1:CLS | Early1:ALL | Insect/Disease | 0.0030 | 1.0000 | Yes | |
| SpruceFir | Late1:CLS | Early1:ALL | ReplacementFire | 0.0010 | 1.0000 | Yes | |
| SpruceFir | Late1:CLS | Early1:ALL | Wind/Weather/Stress | 0.0030 | 1.0000 | Yes | |
| SpruceFir | Late1:CLS | Late1:OPN | Insect/Disease | 0.0100 | 1.0000 | No | |
| SpruceFir | Late1:CLS | Late1:OPN | MixedFire | 0.0010 | 1.0000 | No | |
| SpruceFir | Late1:CLS | Late1:OPN | Wind/Weather/Stress | 0.0040 | 1.0000 | No | |
| SpruceFir | Late1:OPN | Early1:ALL | ReplacementFire | 0.0010 | 1.0000 | Yes | |
| SpruceFir | Late1:OPN | Late1:CLS | AltSuccession | 1.0000 | 1.0000 | No | 33 |
| SpruceFir | Late1:OPN | Late1:OPN | Insect/Disease | 0.0067 | 1.0000 | No | |
| SpruceFir | Late1:OPN | Late1:OPN | MixedFire | 0.0010 | 1.0000 | No | |
| SpruceFir | Late1:OPN | Late1:OPN | Wind/Weather/Stress | 0.0067 | 1.0000 | No | |
| SpruceFir | Late2:CLS | Early1:ALL | Insect/Disease | 0.0030 | 1.0000 | Yes | |
| SpruceFir | Late2:CLS | Early1:ALL | ReplacementFire | 0.0010 | 1.0000 | Yes | |
| SpruceFir | Late2:CLS | Early1:ALL | Wind/Weather/Stress | 0.0030 | 1.0000 | Yes | |
| SpruceFir | Late2:CLS | Late2:OPN | Insect/Disease | 0.0030 | 1.0000 | No | |
| SpruceFir | Late2:CLS | Late2:OPN | MixedFire | 0.0010 | 1.0000 | No | |
| SpruceFir | Late2:CLS | Late2:OPN | Wind/Weather/Stress | 0.0040 | 1.0000 | No | |
| SpruceFir | Late2:OPN | Early1:ALL | ReplacementFire | 0.0010 | 1.0000 | Yes | |
| SpruceFir | Late2:OPN | Late2:CLS | AltSuccession | 1.0000 | 1.0000 | No | 33 |
| SpruceFir | Late2:OPN | Late2:OPN | Insect/Disease | 0.0067 | 1.0000 | No | |
| SpruceFir | Late2:OPN | Late2:OPN | MixedFire | 0.0010 | 1.0000 | No | |
| SpruceFir | Late2:OPN | Late2:OPN | Wind/Weather/Stress | 0.0067 | 1.0000 | No | |
| SpruceFir | Mid1:CLS | Early1:ALL | Insect/Disease | 0.0050 | 1.0000 | Yes | |
| SpruceFir | Mid1:CLS | Early1:ALL | ReplacementFire | 0.0010 | 1.0000 | Yes | |
| SpruceFir | Mid1:CLS | Mid1:OPN | Insect/Disease | 0.0100 | 1.0000 | No | |
| SpruceFir | Mid1:CLS | Mid1:OPN | MixedFire | 0.0010 | 1.0000 | No | |
| SpruceFir | Mid1:CLS | Mid1:OPN | Wind/Weather/Stress | 0.0067 | 1.0000 | No | |
| SpruceFir | Mid1:OPN | Early1:ALL | ReplacementFire | 0.0010 | 1.0000 | Yes | |
| SpruceFir | Mid1:OPN | Mid1:CLS | AltSuccession | 1.0000 | 1.0000 | No | 33 |
| SpruceFir | Mid1:OPN | Mid1:OPN | Insect/Disease | 0.0067 | 1.0000 | No | |
| SpruceFir | Mid1:OPN | Mid1:OPN | MixedFire | 0.0010 | 1.0000 | No | |
| SpruceFir | Mid1:OPN | Mid1:OPN | Wind/Weather/Stress | 0.0067 | 1.0000 | No | |

| From Vegetation Type | From Class | To Class | Transition Type | Prob | Propn | Age Reset | TST Min |
|---|---|---|---|---|---|---|---|
| HighElevRedOak | Early1:ALL | Early1:ALL | MixedFire | 0.0100 | 1.0000 | No | |
| HighElevRedOak | Early1:ALL | Early1:ALL | ReplacementFire | 0.0100 | 1.0000 | Yes | |
| HighElevRedOak | Early1:ALL | Early1:ALL | SurfaceFire | 0.0330 | 1.0000 | No | |
| HighElevRedOak | Early1:ALL | Mid1:CLS | AltSuccession | 1.0000 | 1.0000 | Yes | 19 |
| HighElevRedOak | Late1:CLS | Early1:ALL | Optional1 | 0.0040 | 1.0000 | Yes | |
| HighElevRedOak | Late1:CLS | Early1:ALL | ReplacementFire | 0.0033 | 1.0000 | Yes | |
| HighElevRedOak | Late1:CLS | Early1:ALL | Wind/Weather/Stress | 0.0033 | 1.0000 | Yes | |
| HighElevRedOak | Late1:CLS | Late1:CLS | SurfaceFire | 0.0330 | 1.0000 | No | |
| HighElevRedOak | Late1:CLS | Late1:OPN | Insect/Disease | 0.0067 | 1.0000 | No | |
| HighElevRedOak | Late1:CLS | Late1:OPN | MixedFire | 0.0100 | 1.0000 | No | |
| HighElevRedOak | Late1:CLS | Late1:OPN | Wind/Weather/Stress | 0.0050 | 1.0000 | No | |
| HighElevRedOak | Late1:OPN | Early1:ALL | Optional1 | 0.0040 | 1.0000 | Yes | |
| HighElevRedOak | Late1:OPN | Early1:ALL | ReplacementFire | 0.0020 | 1.0000 | Yes | |
| HighElevRedOak | Late1:OPN | Early1:ALL | Wind/Weather/Stress | 0.0033 | 1.0000 | Yes | |
| HighElevRedOak | Late1:OPN | Late1:CLS | AltSuccession | 1.0000 | 1.0000 | No | 20 |
| HighElevRedOak | Late1:OPN | Late1:OPN | Insect/Disease | 0.0067 | 1.0000 | No | |
| HighElevRedOak | Late1:OPN | Late1:OPN | MixedFire | 0.0100 | 1.0000 | No | |
| HighElevRedOak | Late1:OPN | Late1:OPN | SurfaceFire | 0.0330 | 1.0000 | No | |
| HighElevRedOak | Late1:OPN | Late1:OPN | Wind/Weather/Stress | 0.0050 | 1.0000 | No | |
| HighElevRedOak | Late2:CLS | Early1:ALL | Optional1 | 0.0040 | 1.0000 | Yes | |
| HighElevRedOak | Late2:CLS | Early1:ALL | ReplacementFire | 0.0033 | 1.0000 | Yes | |
| HighElevRedOak | Late2:CLS | Early1:ALL | Wind/Weather/Stress | 0.0033 | 1.0000 | Yes | |
| HighElevRedOak | Late2:CLS | Late2:CLS | SurfaceFire | 0.0330 | 1.0000 | No | |
| HighElevRedOak | Late2:CLS | Late2:OPN | Insect/Disease | 0.0670 | 1.0000 | No | |
| HighElevRedOak | Late2:CLS | Late2:OPN | MixedFire | 0.0100 | 1.0000 | No | |
| HighElevRedOak | Late2:CLS | Late2:OPN | Wind/Weather/Stress | 0.0050 | 1.0000 | No | |
| HighElevRedOak | Late2:OPN | Early1:ALL | Optional1 | 0.0040 | 1.0000 | Yes | |
| HighElevRedOak | Late2:OPN | Early1:ALL | ReplacementFire | 0.0020 | 1.0000 | Yes | |
| HighElevRedOak | Late2:OPN | Early1:ALL | Wind/Weather/Stress | 0.0033 | 1.0000 | Yes | |
| HighElevRedOak | Late2:OPN | Late2:CLS | AltSuccession | 1.0000 | 1.0000 | No | 20 |
| HighElevRedOak | Late2:OPN | Late2:OPN | Insect/Disease | 0.0067 | 1.0000 | No | |
| HighElevRedOak | Late2:OPN | Late2:OPN | MixedFire | 0.0100 | 1.0000 | No | |
| HighElevRedOak | Late2:OPN | Late2:OPN | SurfaceFire | 0.0330 | 1.0000 | No | |
| HighElevRedOak | Late2:OPN | Late2:OPN | Wind/Weather/Stress | 0.0050 | 1.0000 | No | |
| HighElevRedOak | Mid1:CLS | Early1:ALL | Optional1 | 0.0040 | 1.0000 | Yes | |
| HighElevRedOak | Mid1:CLS | Early1:ALL | ReplacementFire | 0.0033 | 1.0000 | Yes | |
| HighElevRedOak | Mid1:CLS | Mid1:CLS | SurfaceFire | 0.0330 | 1.0000 | No | |
| HighElevRedOak | Mid1:CLS | Mid1:OPN | MixedFire | 0.0100 | 1.0000 | No | |
| HighElevRedOak | Mid1:CLS | Mid1:OPN | Wind/Weather/Stress | 0.0050 | 1.0000 | No | |
| HighElevRedOak | Mid1:OPN | Early1:ALL | Optional1 | 0.0040 | 1.0000 | Yes | |
| HighElevRedOak | Mid1:OPN | Early1:ALL | ReplacementFire | 0.0020 | 1.0000 | Yes | |
| HighElevRedOak | Mid1:OPN | Mid1:CLS | AltSuccession | 1.0000 | 1.0000 | No | 20 |
| HighElevRedOak | Mid1:OPN | Mid1:OPN | MixedFire | 0.0100 | 1.0000 | No | |
| HighElevRedOak | Mid1:OPN | Mid1:OPN | SurfaceFire | 0.0330 | 1.0000 | No | |
| HighElevRedOak | Mid1:OPN | Mid1:OPN | Wind/Weather/Stress | 0.0050 | 1.0000 | No | |

| From Vegetation Type | From Class | To Class | Transition Type | Prob | Propn | Age Reset | TST Min |
|---|---|---|---|---|---|---|---|
| NorthernHardwood | Early1:ALL | Early1:ALL | ReplacementFire | 0.0015 | 1.0000 | Yes | |
| NorthernHardwood | Early1:ALL | Early1:ALL | SurfaceFire | 0.0030 | 1.0000 | No | |
| NorthernHardwood | Early1:ALL | Mid1:OPN | MixedFire | 0.0020 | 1.0000 | Yes | |
| NorthernHardwood | Late1:CLS | Early1:ALL | Optional1 | 0.0030 | 1.0000 | Yes | |
| NorthernHardwood | Late1:CLS | Early1:ALL | ReplacementFire | 0.0015 | 1.0000 | Yes | |
| NorthernHardwood | Late1:CLS | Late1:CLS | SurfaceFire | 0.0030 | 1.0000 | No | |
| NorthernHardwood | Late1:CLS | Late1:OPN | Insect/Disease | 0.0050 | 1.0000 | No | |
| NorthernHardwood | Late1:CLS | Late1:OPN | MixedFire | 0.0015 | 1.0000 | No | |
| NorthernHardwood | Late1:CLS | Late1:OPN | Wind/Weather/Stress | 0.0025 | 1.0000 | No | |
| NorthernHardwood | Late1:OPN | Early1:ALL | Optional1 | 0.0030 | 1.0000 | Yes | |
| NorthernHardwood | Late1:OPN | Early1:ALL | ReplacementFire | 0.0015 | 1.0000 | Yes | |
| NorthernHardwood | Late1:OPN | Late1:CLS | AltSuccession | 1.0000 | 1.0000 | No | 25 |
| NorthernHardwood | Late1:OPN | Late1:OPN | Insect/Disease | 0.0050 | 1.0000 | No | |
| NorthernHardwood | Late1:OPN | Late1:OPN | MixedFire | 0.0010 | 1.0000 | No | |
| NorthernHardwood | Late1:OPN | Late1:OPN | SurfaceFire | 0.0030 | 1.0000 | No | |
| NorthernHardwood | Late1:OPN | Late1:OPN | Wind/Weather/Stress | 0.0070 | 1.0000 | No | |
| NorthernHardwood | Late2:CLS | Early1:ALL | Optional1 | 0.0030 | 1.0000 | Yes | |
| NorthernHardwood | Late2:CLS | Early1:ALL | ReplacementFire | 0.0015 | 1.0000 | Yes | |
| NorthernHardwood | Late2:CLS | Late2:CLS | SurfaceFire | 0.0030 | 1.0000 | No | |
| NorthernHardwood | Late2:CLS | Late2:OPN | Insect/Disease | 0.0050 | 1.0000 | No | |
| NorthernHardwood | Late2:CLS | Late2:OPN | MixedFire | 0.0015 | 1.0000 | No | |
| NorthernHardwood | Late2:CLS | Late2:OPN | Wind/Weather/Stress | 0.0025 | 1.0000 | No | |
| NorthernHardwood | Late2:OPN | Early1:ALL | Optional1 | 0.0030 | 1.0000 | Yes | |
| NorthernHardwood | Late2:OPN | Early1:ALL | ReplacementFire | 0.0015 | 1.0000 | Yes | |
| NorthernHardwood | Late2:OPN | Late2:CLS | AltSuccession | 1.0000 | 1.0000 | No | 25 |
| NorthernHardwood | Late2:OPN | Late2:OPN | Insect/Disease | 0.0050 | 1.0000 | No | |
| NorthernHardwood | Late2:OPN | Late2:OPN | MixedFire | 0.0010 | 1.0000 | No | |
| NorthernHardwood | Late2:OPN | Late2:OPN | SurfaceFire | 0.0030 | 1.0000 | No | |
| NorthernHardwood | Late2:OPN | Late2:OPN | Wind/Weather/Stress | 0.0070 | 1.0000 | No | |
| NorthernHardwood | Mid1:CLS | Early1:ALL | Optional1 | 0.0030 | 1.0000 | Yes | |
| NorthernHardwood | Mid1:CLS | Early1:ALL | ReplacementFire | 0.0015 | 1.0000 | Yes | |
| NorthernHardwood | Mid1:CLS | Mid1:CLS | SurfaceFire | 0.0030 | 1.0000 | No | |
| NorthernHardwood | Mid1:CLS | Mid1:OPN | MixedFire | 0.0015 | 1.0000 | No | |
| NorthernHardwood | Mid1:CLS | Mid1:OPN | Wind/Weather/Stress | 0.0025 | 1.0000 | No | |
| NorthernHardwood | Mid1:OPN | Early1:ALL | Optional1 | 0.0030 | 1.0000 | Yes | |
| NorthernHardwood | Mid1:OPN | Early1:ALL | ReplacementFire | 0.0015 | 1.0000 | | |
| NorthernHardwood | Mid1:OPN | Mid1:CLS | AltSuccession | 1.0000 | 1.0000 | No | 25 |
| NorthernHardwood | Mid1:OPN | Mid1:OPN | MixedFire | 0.0020 | 1.0000 | No | |
| NorthernHardwood | Mid1:OPN | Mid1:OPN | SurfaceFire | 0.0030 | 1.0000 | No | |
| NorthernHardwood | Mid1:OPN | Mid1:OPN | Wind/Weather/Stress | 0.0070 | 1.0000 | No | |

| From Vegetation Type | From Class | To Class | Transition Type | Prob | Propn | Age Reset | TST Min |
|---|---|---|---|---|---|---|---|
| RichAcidicCove | Early1:ALL | Early1:ALL | MixedFire | 0.0020 | 1.0000 | No | |
| RichAcidicCove | Early1:ALL | Early1:ALL | ReplacementFire | 0.0010 | 1.0000 | Yes | |
| RichAcidicCove | Early1:ALL | Early1:ALL | SurfaceFire | 0.0100 | 1.0000 | No | |
| RichAcidicCove | Late1:CLS | Early1:ALL | Optional1 | 0.0020 | 1.0000 | Yes | |
| RichAcidicCove | Late1:CLS | Early1:ALL | ReplacementFire | 0.0010 | 1.0000 | Yes | |
| RichAcidicCove | Late1:CLS | Early1:ALL | Wind/Weather/Stress | 0.0020 | 1.0000 | Yes | |
| RichAcidicCove | Late1:CLS | Late1:CLS | SurfaceFire | 0.0100 | 1.0000 | No | |
| RichAcidicCove | Late1:CLS | Late1:OPN | Insect/Disease | 0.0040 | 1.0000 | No | |
| RichAcidicCove | Late1:CLS | Late1:OPN | MixedFire | 0.0020 | 1.0000 | No | |
| RichAcidicCove | Late1:CLS | Late1:OPN | Wind/Weather/Stress | 0.0030 | 1.0000 | No | |
| RichAcidicCove | Late1:OPN | Early1:ALL | Optional1 | 0.0020 | 1.0000 | Yes | |
| RichAcidicCove | Late1:OPN | Early1:ALL | ReplacementFire | 0.0010 | 1.0000 | Yes | |
| RichAcidicCove | Late1:OPN | Early1:ALL | Wind/Weather/Stress | 0.0020 | 1.0000 | Yes | |
| RichAcidicCove | Late1:OPN | Late1:CLS | AltSuccession | 1.0000 | 1.0000 | No | 20 |
| RichAcidicCove | Late1:OPN | Late1:OPN | Insect/Disease | 0.0040 | 1.0000 | No | |
| RichAcidicCove | Late1:OPN | Late1:OPN | MixedFire | 0.0020 | 1.0000 | No | |
| RichAcidicCove | Late1:OPN | Late1:OPN | SurfaceFire | 0.0100 | 1.0000 | No | |
| RichAcidicCove | Late2:ALL | Early1:ALL | Optional1 | 0.0020 | 1.0000 | Yes | |
| RichAcidicCove | Late2:ALL | Early1:ALL | ReplacementFire | 0.0010 | 1.0000 | Yes | |
| RichAcidicCove | Late2:ALL | Early1:ALL | Wind/Weather/Stress | 0.0020 | 1.0000 | Yes | |
| RichAcidicCove | Late2:ALL | Late2:ALL | Insect/Disease | 0.0040 | 1.0000 | No | |
| RichAcidicCove | Late2:ALL | Late2:ALL | MixedFire | 0.0020 | 1.0000 | No | |
| RichAcidicCove | Late2:ALL | Late2:ALL | SurfaceFire | 0.0100 | 1.0000 | No | |
| RichAcidicCove | Late2:ALL | Late2:ALL | Wind/Weather/Stress | 0.0030 | 1.0000 | No | |
| RichAcidicCove | Mid1:CLS | Early1:ALL | Optional1 | 0.0020 | 1.0000 | Yes | |
| RichAcidicCove | Mid1:CLS | Early1:ALL | ReplacementFire | 0.0010 | 1.0000 | Yes | |
| RichAcidicCove | Mid1:CLS | Early1:ALL | Wind/Weather/Stress | 0.0020 | 1.0000 | Yes | |
| RichAcidicCove | Mid1:CLS | Mid1:CLS | SurfaceFire | 0.0100 | 1.0000 | No | |
| RichAcidicCove | Mid1:CLS | Mid1:OPN | Insect/Disease | 0.0040 | 1.0000 | No | |
| RichAcidicCove | Mid1:CLS | Mid1:OPN | MixedFire | 0.0020 | 1.0000 | No | |
| RichAcidicCove | Mid1:CLS | Mid1:OPN | Wind/Weather/Stress | 0.0030 | 1.0000 | No | |
| RichAcidicCove | Mid1:OPN | Early1:ALL | Optional1 | 0.0020 | 1.0000 | Yes | |
| RichAcidicCove | Mid1:OPN | Early1:ALL | ReplacementFire | 0.0010 | 1.0000 | Yes | |
| RichAcidicCove | Mid1:OPN | Mid1:CLS | AltSuccession | 1.0000 | 1.0000 | No | 20 |
| RichAcidicCove | Mid1:OPN | Mid1:OPN | Insect/Disease | 0.0040 | 1.0000 | No | |
| RichAcidicCove | Mid1:OPN | Mid1:OPN | MixedFire | 0.0020 | 1.0000 | No | |
| RichAcidicCove | Mid1:OPN | Mid1:OPN | SurfaceFire | 0.0100 | 1.0000 | No | |
| RichAcidicCove | Mid1:OPN | Mid1:OPN | Wind/Weather/Stress | 0.0030 | 1.0000 | No | |

| From Vegetation Type | From Class | To Class | Transition Type | Prob | Propn | Age Reset | TST Min |
|---|---|---|---|---|---|---|---|
| MesicOak | Early1:ALL | Early1:ALL | MixedFire | 0.0100 | 1.0000 | No | |
| MesicOak | Early1:ALL | Early1:ALL | ReplacementFire | 0.0033 | 1.0000 | Yes | |
| MesicOak | Early1:ALL | Early1:ALL | SurfaceFire | 0.0330 | 1.0000 | No | |
| MesicOak | Early1:ALL | Mid1:CLS | AltSuccession | 1.0000 | 1.0000 | Yes | 20 |
| MesicOak | Late1:CLS | Early1:ALL | ReplacementFire | 0.0025 | 1.0000 | Yes | |
| MesicOak | Late1:CLS | Early1:ALL | Wind/Weather/Stress | 0.0050 | 1.0000 | Yes | |
| MesicOak | Late1:CLS | Late1:CLS | SurfaceFire | 0.0330 | 1.0000 | No | |
| MesicOak | Late1:CLS | Late1:OPN | Insect/Disease | 0.0050 | 1.0000 | No | |
| MesicOak | Late1:CLS | Late1:OPN | MixedFire | 0.0100 | 1.0000 | No | |
| MesicOak | Late1:CLS | Late1:OPN | Wind/Weather/Stress | 0.0050 | 1.0000 | No | |
| MesicOak | Late1:OPN | Early1:ALL | ReplacementFire | 0.0020 | 1.0000 | Yes | |
| MesicOak | Late1:OPN | Early1:ALL | Wind/Weather/Stress | 0.0050 | 1.0000 | Yes | |
| MesicOak | Late1:OPN | Late1:CLS | AltSuccession | 1.0000 | 1.0000 | No | 20 |
| MesicOak | Late1:OPN | Late1:OPN | Insect/Disease | 0.0050 | 1.0000 | No | |
| MesicOak | Late1:OPN | Late1:OPN | MixedFire | 0.0100 | 1.0000 | No | |
| MesicOak | Late1:OPN | Late1:OPN | SurfaceFire | 0.0330 | 1.0000 | No | |
| MesicOak | Late1:OPN | Late1:OPN | Wind/Weather/Stress | 0.0050 | 1.0000 | No | |
| MesicOak | Late2:CLS | Early1:ALL | ReplacementFire | 0.0025 | 1.0000 | Yes | |
| MesicOak | Late2:CLS | Early1:ALL | Wind/Weather/Stress | 0.0050 | 1.0000 | Yes | |
| MesicOak | Late2:CLS | Late2:CLS | SurfaceFire | 0.0330 | 1.0000 | No | |
| MesicOak | Late2:CLS | Late2:OPN | Insect/Disease | 0.0050 | 1.0000 | No | |
| MesicOak | Late2:CLS | Late2:OPN | MixedFire | 0.0100 | 1.0000 | No | |
| MesicOak | Late2:CLS | Late2:OPN | Wind/Weather/Stress | 0.0050 | 1.0000 | No | |
| MesicOak | Late2:OPN | Early1:ALL | ReplacementFire | 0.0020 | 1.0000 | Yes | |
| MesicOak | Late2:OPN | Early1:ALL | Wind/Weather/Stress | 0.0050 | 1.0000 | Yes | |
| MesicOak | Late2:OPN | Late2:CLS | AltSuccession | 1.0000 | 1.0000 | No | 20 |
| MesicOak | Late2:OPN | Late2:OPN | Insect/Disease | 0.0050 | 1.0000 | No | |
| MesicOak | Late2:OPN | Late2:OPN | MixedFire | 0.0100 | 1.0000 | No | |
| MesicOak | Late2:OPN | Late2:OPN | SurfaceFire | 0.0330 | 1.0000 | No | |
| MesicOak | Late2:OPN | Late2:OPN | Wind/Weather/Stress | 0.0050 | 1.0000 | No | |
| MesicOak | Mid1:CLS | Early1:ALL | ReplacementFire | 0.0025 | 1.0000 | Yes | |
| MesicOak | Mid1:CLS | Early1:ALL | Wind/Weather/Stress | 0.0050 | 1.0000 | Yes | |
| MesicOak | Mid1:CLS | Mid1:CLS | SurfaceFire | 0.0330 | 1.0000 | No | |
| MesicOak | Mid1:CLS | Mid1:OPN | MixedFire | 0.0100 | 1.0000 | No | |
| MesicOak | Mid1:CLS | Mid1:OPN | Wind/Weather/Stress | 0.0050 | 1.0000 | No | |
| MesicOak | Mid1:OPN | Early1:ALL | ReplacementFire | 0.0020 | 1.0000 | Yes | |
| MesicOak | Mid1:OPN | Early1:ALL | Wind/Weather/Stress | 0.0050 | 1.0000 | Yes | |
| MesicOak | Mid1:OPN | Mid1:CLS | AltSuccession | 1.0000 | 1.0000 | No | 20 |
| MesicOak | Mid1:OPN | Mid1:OPN | MixedFire | 0.0100 | 1.0000 | No | |
| MesicOak | Mid1:OPN | Mid1:OPN | SurfaceFire | 0.0330 | 1.0000 | No | |
| MesicOak | Mid1:OPN | Mid1:OPN | Wind/Weather/Stress | 0.0050 | 1.0000 | No | |

| From Vegetation Type | From Class | To Class | Transition Type | Prob | Propn | Age Reset | TST Min |
|---|---|---|---|---|---|---|---|
| DryMesicOak | Early1:ALL | Early1:ALL | ReplacementFire | 0.0033 | 1.0000 | Yes | |
| DryMesicOak | Early1:ALL | Early1:ALL | SurfaceFire | 0.0400 | 1.0000 | No | |
| DryMesicOak | Early1:ALL | Mid1:CLS | AltSuccession | 1.0000 | 1.0000 | Yes | 18 |
| DryMesicOak | Early1:ALL | Mid1:OPN | MixedFire | 0.0100 | 1.0000 | Yes | |
| DryMesicOak | Late1:CLS | Early1:ALL | ReplacementFire | 0.0025 | 1.0000 | Yes | |
| DryMesicOak | Late1:CLS | Early1:ALL | Wind/Weather/Stress | 0.0025 | 1.0000 | Yes | |
| DryMesicOak | Late1:CLS | Late1:CLS | SurfaceFire | 0.0400 | 1.0000 | No | |
| DryMesicOak | Late1:CLS | Late1:OPN | Insect/Disease | 0.0050 | 1.0000 | No | |
| DryMesicOak | Late1:CLS | Late1:OPN | MixedFire | 0.0100 | 1.0000 | No | |
| DryMesicOak | Late1:CLS | Late1:OPN | Wind/Weather/Stress | 0.0050 | 1.0000 | No | |
| DryMesicOak | Late1:OPN | Early1:ALL | ReplacementFire | 0.0020 | 1.0000 | Yes | |
| DryMesicOak | Late1:OPN | Early1:ALL | Wind/Weather/Stress | 0.0025 | 1.0000 | Yes | |
| DryMesicOak | Late1:OPN | Late1:CLS | AltSuccession | 1.0000 | 1.0000 | No | 25 |
| DryMesicOak | Late1:OPN | Late1:OPN | Insect/Disease | 0.0050 | 1.0000 | No | |
| DryMesicOak | Late1:OPN | Late1:OPN | MixedFire | 0.0100 | 1.0000 | No | |
| DryMesicOak | Late1:OPN | Late1:OPN | SurfaceFire | 0.0400 | 1.0000 | No | |
| DryMesicOak | Late1:OPN | Late1:OPN | Wind/Weather/Stress | 0.0050 | 1.0000 | No | |
| DryMesicOak | Late2:CLS | Early1:ALL | ReplacementFire | 0.0025 | 1.0000 | Yes | |
| DryMesicOak | Late2:CLS | Early1:ALL | Wind/Weather/Stress | 0.0025 | 1.0000 | Yes | |
| DryMesicOak | Late2:CLS | Late2:CLS | SurfaceFire | 0.0400 | 1.0000 | No | |
| DryMesicOak | Late2:CLS | Late2:OPN | Insect/Disease | 0.0050 | 1.0000 | No | |
| DryMesicOak | Late2:CLS | Late2:OPN | MixedFire | 0.0100 | 1.0000 | No | |
| DryMesicOak | Late2:CLS | Late2:OPN | Wind/Weather/Stress | 0.0050 | 1.0000 | No | |
| DryMesicOak | Late2:OPN | Early1:ALL | ReplacementFire | 0.0020 | 1.0000 | Yes | |
| DryMesicOak | Late2:OPN | Early1:ALL | Wind/Weather/Stress | 0.0025 | 1.0000 | Yes | |
| DryMesicOak | Late2:OPN | Late2:CLS | AltSuccession | 1.0000 | 1.0000 | No | 25 |
| DryMesicOak | Late2:OPN | Late2:OPN | Insect/Disease | 0.0050 | 1.0000 | No | |
| DryMesicOak | Late2:OPN | Late2:OPN | MixedFire | 0.0100 | 1.0000 | No | |
| DryMesicOak | Late2:OPN | Late2:OPN | SurfaceFire | 0.0400 | 1.0000 | No | |
| DryMesicOak | Late2:OPN | Late2:OPN | Wind/Weather/Stress | 0.0050 | 1.0000 | No | |
| DryMesicOak | Mid1:CLS | Early1:ALL | ReplacementFire | 0.0025 | 1.0000 | Yes | |
| DryMesicOak | Mid1:CLS | Early1:ALL | Wind/Weather/Stress | 0.0025 | 1.0000 | Yes | |
| DryMesicOak | Mid1:CLS | Mid1:CLS | SurfaceFire | 0.0400 | 1.0000 | No | |
| DryMesicOak | Mid1:CLS | Mid1:OPN | MixedFire | 0.0100 | 1.0000 | No | |
| DryMesicOak | Mid1:CLS | Mid1:OPN | Wind/Weather/Stress | 0.0050 | 1.0000 | No | |
| DryMesicOak | Mid1:OPN | Early1:ALL | ReplacementFire | 0.0020 | 1.0000 | Yes | |
| DryMesicOak | Mid1:OPN | Early1:ALL | Wind/Weather/Stress | 0.0025 | 1.0000 | Yes | |
| DryMesicOak | Mid1:OPN | Mid1:CLS | AltSuccession | 1.0000 | 1.0000 | No | 25 |
| DryMesicOak | Mid1:OPN | Mid1:OPN | MixedFire | 0.0100 | 1.0000 | No | |
| DryMesicOak | Mid1:OPN | Mid1:OPN | SurfaceFire | 0.0400 | 1.0000 | No | |
| DryMesicOak | Mid1:OPN | Mid1:OPN | Wind/Weather/Stress | 0.0050 | 1.0000 | No | |

| From Vegetation Type | From Class | To Class | Transition Type | Prob | Propn | Age Reset | TST Min |
|---|---|---|---|---|---|---|---|
| DryOak | Early1:ALL | Early1:ALL | MixedFire | 0.0400 | 1.0000 | No | |
| DryOak | Early1:ALL | Early1:ALL | ReplacementFire | 0.0400 | 1.0000 | Yes | |
| DryOak | Early1:ALL | Early1:ALL | SurfaceFire | 0.1000 | 1.0000 | No | |
| DryOak | Early1:ALL | Mid1:CLS | AltSuccession | 1.0000 | 1.0000 | Yes | 19 |
| DryOak | Late1:CLS | Early1:ALL | ReplacementFire | 0.0033 | 1.0000 | Yes | |
| DryOak | Late1:CLS | Early1:ALL | Wind/Weather/Stress | 0.0030 | 1.0000 | Yes | |
| DryOak | Late1:CLS | Late1:CLS | SurfaceFire | 0.1000 | 1.0000 | No | |
| DryOak | Late1:CLS | Late1:OPN | Insect/Disease | 0.0100 | 1.0000 | No | |
| DryOak | Late1:CLS | Late1:OPN | MixedFire | 0.0100 | 1.0000 | No | |
| DryOak | Late1:CLS | Late1:OPN | Wind/Weather/Stress | 0.0200 | 1.0000 | No | |
| DryOak | Late1:OPN | Early1:ALL | ReplacementFire | 0.0020 | 1.0000 | Yes | |
| DryOak | Late1:OPN | Early1:ALL | Wind/Weather/Stress | 0.0030 | 1.0000 | Yes | |
| DryOak | Late1:OPN | Late1:CLS | AltSuccession | 1.0000 | 1.0000 | No | 20 |
| DryOak | Late1:OPN | Late1:OPN | Insect/Disease | 0.0100 | 1.0000 | No | |
| DryOak | Late1:OPN | Late1:OPN | MixedFire | 0.0150 | 1.0000 | No | |
| DryOak | Late1:OPN | Late1:OPN | SurfaceFire | 0.1000 | 1.0000 | No | |
| DryOak | Late1:OPN | Late1:OPN | Wind/Weather/Stress | 0.0200 | 1.0000 | No | |
| DryOak | Late2:CLS | Early1:ALL | ReplacementFire | 0.0033 | 1.0000 | Yes | |
| DryOak | Late2:CLS | Early1:ALL | Wind/Weather/Stress | 0.0030 | 1.0000 | Yes | |
| DryOak | Late2:CLS | Late2:CLS | SurfaceFire | 0.1000 | 1.0000 | No | |
| DryOak | Late2:CLS | Late2:OPN | Insect/Disease | 0.0100 | 1.0000 | No | |
| DryOak | Late2:CLS | Late2:OPN | MixedFire | 0.0100 | 1.0000 | No | |
| DryOak | Late2:CLS | Late2:OPN | Wind/Weather/Stress | 0.0200 | 1.0000 | No | |
| DryOak | Late2:OPN | Early1:ALL | ReplacementFire | 0.0020 | 1.0000 | Yes | |
| DryOak | Late2:OPN | Early1:ALL | Wind/Weather/Stress | 0.0030 | 1.0000 | Yes | |
| DryOak | Late2:OPN | Late2:CLS | AltSuccession | 1.0000 | 1.0000 | No | 20 |
| DryOak | Late2:OPN | Late2:OPN | Insect/Disease | 0.0100 | 1.0000 | No | |
| DryOak | Late2:OPN | Late2:OPN | MixedFire | 0.0150 | 1.0000 | No | |
| DryOak | Late2:OPN | Late2:OPN | SurfaceFire | 0.1000 | 1.0000 | No | |
| DryOak | Late2:OPN | Late2:OPN | Wind/Weather/Stress | 0.0200 | 1.0000 | No | |
| DryOak | Mid1:CLS | Early1:ALL | ReplacementFire | 0.0033 | 1.0000 | Yes | |
| DryOak | Mid1:CLS | Mid1:CLS | Insect/Disease | 0.0067 | 1.0000 | No | |
| DryOak | Mid1:CLS | Mid1:CLS | SurfaceFire | 0.1000 | 1.0000 | No | |
| DryOak | Mid1:CLS | Mid1:OPN | MixedFire | 0.0100 | 1.0000 | No | |
| DryOak | Mid1:CLS | Mid1:OPN | Wind/Weather/Stress | 0.0100 | 1.0000 | No | |
| DryOak | Mid1:OPN | Early1:ALL | ReplacementFire | 0.0020 | 1.0000 | Yes | |
| DryOak | Mid1:OPN | Mid1:CLS | AltSuccession | 1.0000 | 1.0000 | No | 20 |
| DryOak | Mid1:OPN | Mid1:OPN | Insect/Disease | 0.0067 | 1.0000 | No | |
| DryOak | Mid1:OPN | Mid1:OPN | MixedFire | 0.0150 | 1.0000 | No | |
| DryOak | Mid1:OPN | Mid1:OPN | SurfaceFire | 0.1000 | 1.0000 | No | |
| DryOak | Mid1:OPN | Mid1:OPN | Wind/Weather/Stress | 0.0100 | 1.0000 | No | |

| From Vegetation Type | From Class | To Class | Transition Type | Prob | Propn | Age Reset | TST Min |
|---|---|---|---|---|---|---|---|
| PineOakHeath | Early1:ALL | Early1:ALL | ReplacementFire | 0.0330 | 1.0000 | Yes | |
| PineOakHeath | Early1:ALL | Early1:ALL | SurfaceFire | 0.2000 | 1.0000 | No | |
| PineOakHeath | Early1:ALL | Mid1:CLS | AltSuccession | 1.0000 | 1.0000 | Yes | 14 |
| PineOakHeath | Early1:ALL | Mid1:OPN | MixedFire | 0.0500 | 1.0000 | Yes | |
| PineOakHeath | Late1:CLS | Early1:ALL | Insect/Disease | 0.0130 | 1.0000 | Yes | |
| PineOakHeath | Late1:CLS | Early1:ALL | ReplacementFire | 0.0050 | 1.0000 | Yes | |
| PineOakHeath | Late1:CLS | Early1:ALL | Wind/Weather/Stress | 0.0033 | 1.0000 | Yes | |
| PineOakHeath | Late1:CLS | Late1:CLS | SurfaceFire | 0.2000 | 1.0000 | No | |
| PineOakHeath | Late1:CLS | Late1:OPN | MixedFire | 0.0130 | 1.0000 | No | |
| PineOakHeath | Late1:CLS | Late1:OPN | Optional1 | 0.0040 | 1.0000 | No | |
| PineOakHeath | Late1:CLS | Late1:OPN | Wind/Weather/Stress | 0.0100 | 1.0000 | No | |
| PineOakHeath | Late1:OPN | Early1:ALL | Insect/Disease | 0.0067 | 1.0000 | Yes | |
| PineOakHeath | Late1:OPN | Early1:ALL | ReplacementFire | 0.0033 | 1.0000 | Yes | |
| PineOakHeath | Late1:OPN | Early1:ALL | Wind/Weather/Stress | 0.0033 | 1.0000 | Yes | |
| PineOakHeath | Late1:OPN | Late1:CLS | AltSuccession | 1.0000 | 1.0000 | No | 20 |
| PineOakHeath | Late1:OPN | Late1:OPN | MixedFire | 0.0100 | 1.0000 | No | |
| PineOakHeath | Late1:OPN | Late1:OPN | SurfaceFire | 0.2000 | 1.0000 | No | |
| PineOakHeath | Late1:OPN | Late1:OPN | Wind/Weather/Stress | 0.0100 | 1.0000 | No | |
| PineOakHeath | Late2:CLS | Early1:ALL | Insect/Disease | 0.0130 | 1.0000 | Yes | |
| PineOakHeath | Late2:CLS | Early1:ALL | ReplacementFire | 0.0050 | 1.0000 | Yes | |
| PineOakHeath | Late2:CLS | Early1:ALL | Wind/Weather/Stress | 0.0033 | 1.0000 | Yes | |
| PineOakHeath | Late2:CLS | Late2:CLS | SurfaceFire | 0.2000 | 1.0000 | No | |
| PineOakHeath | Late2:CLS | Late2:OPN | MixedFire | 0.0130 | 1.0000 | No | |
| PineOakHeath | Late2:CLS | Late2:OPN | Optional1 | 0.0040 | 1.0000 | No | |
| PineOakHeath | Late2:CLS | Late2:OPN | Wind/Weather/Stress | 0.0100 | 1.0000 | No | |
| PineOakHeath | Late2:OPN | Early1:ALL | Insect/Disease | 0.0067 | 1.0000 | Yes | |
| PineOakHeath | Late2:OPN | Early1:ALL | ReplacementFire | 0.0033 | 1.0000 | Yes | |
| PineOakHeath | Late2:OPN | Early1:ALL | Wind/Weather/Stress | 0.0033 | 1.0000 | Yes | |
| PineOakHeath | Late2:OPN | Late2:CLS | AltSuccession | 1.0000 | 1.0000 | No | 20 |
| PineOakHeath | Late2:OPN | Late2:OPN | MixedFire | 0.0100 | 1.0000 | No | |
| PineOakHeath | Late2:OPN | Late2:OPN | SurfaceFire | 0.2000 | 1.0000 | No | |
| PineOakHeath | Late2:OPN | Late2:OPN | Wind/Weather/Stress | 0.0100 | 1.0000 | No | |
| PineOakHeath | Mid1:CLS | Early1:ALL | Insect/Disease | 0.0130 | 1.0000 | Yes | |
| PineOakHeath | Mid1:CLS | Early1:ALL | ReplacementFire | 0.0050 | 1.0000 | Yes | |
| PineOakHeath | Mid1:CLS | Mid1:CLS | SurfaceFire | 0.2000 | 1.0000 | No | |
| PineOakHeath | Mid1:CLS | Mid1:OPN | MixedFire | 0.0200 | 1.0000 | No | |
| PineOakHeath | Mid1:CLS | Mid1:OPN | Optional1 | 0.0040 | 1.0000 | No | |
| PineOakHeath | Mid1:CLS | Mid1:OPN | Wind/Weather/Stress | 0.0100 | 1.0000 | No | |
| PineOakHeath | Mid1:OPN | Early1:ALL | Insect/Disease | 0.0050 | 1.0000 | Yes | |
| PineOakHeath | Mid1:OPN | Early1:ALL | ReplacementFire | 0.0033 | 1.0000 | Yes | |
| PineOakHeath | Mid1:OPN | Mid1:CLS | AltSuccession | 1.0000 | 1.0000 | No | 20 |
| PineOakHeath | Mid1:OPN | Mid1:OPN | MixedFire | 0.0130 | 1.0000 | No | |
| PineOakHeath | Mid1:OPN | Mid1:OPN | SurfaceFire | 0.2000 | 1.0000 | No | |
| PineOakHeath | Mid1:OPN | Mid1:OPN | Wind/Weather/Stress | 0.0100 | 1.0000 | No | |

| From Vegetation Type | From Class | To Class | Transition Type | Prob | Propn | Age Reset | TST Min |
|---|---|---|---|---|---|---|---|
| ShortleafPineOak | Early1:ALL | Early1:ALL | ReplacementFire | 0.0330 | 1.0000 | Yes | |
| ShortleafPineOak | Early1:ALL | Early1:ALL | SurfaceFire | 0.3300 | 1.0000 | No | |
| ShortleafPineOak | Early1:ALL | Mid1:CLS | AltSuccession | 1.0000 | 1.0000 | Yes | 9 |
| ShortleafPineOak | Early1:ALL | Mid1:OPN | MixedFire | 0.0500 | 1.0000 | No | |
| ShortleafPineOak | Late1:CLS | Early1:ALL | Insect/Disease | 0.0100 | 1.0000 | Yes | |
| ShortleafPineOak | Late1:CLS | Early1:ALL | ReplacementFire | 0.0050 | 1.0000 | Yes | |
| ShortleafPineOak | Late1:CLS | Early1:ALL | Wind/Weather/Stress | 0.0030 | 1.0000 | Yes | |
| ShortleafPineOak | Late1:CLS | Late1:CLS | SurfaceFire | 0.1500 | 1.0000 | No | |
| ShortleafPineOak | Late1:CLS | Late1:OPN | MixedFire | 0.0100 | 1.0000 | No | |
| ShortleafPineOak | Late1:CLS | Late1:OPN | Wind/Weather/Stress | 0.0100 | 1.0000 | No | |
| ShortleafPineOak | Late1:OPN | Early1:ALL | Insect/Disease | 0.0067 | 1.0000 | Yes | |
| ShortleafPineOak | Late1:OPN | Early1:ALL | ReplacementFire | 0.0020 | 1.0000 | Yes | |
| ShortleafPineOak | Late1:OPN | Early1:ALL | Wind/Weather/Stress | 0.0030 | 1.0000 | Yes | |
| ShortleafPineOak | Late1:OPN | Late1:CLS | AltSuccession | 1.0000 | 1.0000 | No | 20 |
| ShortleafPineOak | Late1:OPN | Late1:OPN | MixedFire | 0.0150 | 1.0000 | No | |
| ShortleafPineOak | Late1:OPN | Late1:OPN | SurfaceFire | 0.2000 | 1.0000 | No | |
| ShortleafPineOak | Late1:OPN | Late1:OPN | Wind/Weather/Stress | 0.0100 | 1.0000 | No | |
| ShortleafPineOak | Late2:CLS | Early1:ALL | Insect/Disease | 0.0100 | 1.0000 | Yes | |
| ShortleafPineOak | Late2:CLS | Early1:ALL | ReplacementFire | 0.0050 | 1.0000 | Yes | |
| ShortleafPineOak | Late2:CLS | Early1:ALL | Wind/Weather/Stress | 0.0030 | 1.0000 | Yes | |
| ShortleafPineOak | Late2:CLS | Late2:CLS | SurfaceFire | 0.1500 | 1.0000 | No | |
| ShortleafPineOak | Late2:CLS | Late2:OPN | MixedFire | 0.0100 | 1.0000 | No | |
| ShortleafPineOak | Late2:CLS | Late2:OPN | Wind/Weather/Stress | 0.0100 | 1.0000 | No | |
| ShortleafPineOak | Late2:OPN | Early1:ALL | Insect/Disease | 0.0067 | 1.0000 | Yes | |
| ShortleafPineOak | Late2:OPN | Early1:ALL | ReplacementFire | 0.0020 | 1.0000 | Yes | |
| ShortleafPineOak | Late2:OPN | Early1:ALL | Wind/Weather/Stress | 0.0030 | 1.0000 | Yes | |
| ShortleafPineOak | Late2:OPN | Late2:CLS | AltSuccession | 1.0000 | 1.0000 | No | 20 |
| ShortleafPineOak | Late2:OPN | Late2:OPN | MixedFire | 0.0150 | 1.0000 | No | |
| ShortleafPineOak | Late2:OPN | Late2:OPN | SurfaceFire | 0.2000 | 1.0000 | No | |
| ShortleafPineOak | Late2:OPN | Late2:OPN | Wind/Weather/Stress | 0.0100 | 1.0000 | No | |
| ShortleafPineOak | Mid1:CLS | Early1:ALL | Insect/Disease | 0.0100 | 1.0000 | Yes | |
| ShortleafPineOak | Mid1:CLS | Early1:ALL | ReplacementFire | 0.0030 | 1.0000 | Yes | |
| ShortleafPineOak | Mid1:CLS | Mid1:CLS | SurfaceFire | 0.1500 | 1.0000 | No | |
| ShortleafPineOak | Mid1:CLS | Mid1:OPN | MixedFire | 0.0330 | 1.0000 | No | |
| ShortleafPineOak | Mid1:CLS | Mid1:OPN | Wind/Weather/Stress | 0.0100 | 1.0000 | No | |
| ShortleafPineOak | Mid1:OPN | Early1:ALL | Insect/Disease | 0.0050 | 1.0000 | Yes | |
| ShortleafPineOak | Mid1:OPN | Early1:ALL | ReplacementFire | 0.0020 | 1.0000 | Yes | |
| ShortleafPineOak | Mid1:OPN | Mid1:CLS | AltSuccession | 1.0000 | 1.0000 | No | 20 |
| ShortleafPineOak | Mid1:OPN | Mid1:OPN | MixedFire | 0.0100 | 1.0000 | No | |
| ShortleafPineOak | Mid1:OPN | Mid1:OPN | SurfaceFire | 0.2000 | 1.0000 | No | |
| ShortleafPineOak | Mid1:OPN | Mid1:OPN | Wind/Weather/Stress | 0.0100 | 1.0000 | No | |

| From Vegetation Type | From Class | To Class | Transition Type | Prob |
|---|---|---|---|---|
| FloodForest | Early1:ALL | Early1:ALL | MixedFire | 0.0020 |
| FloodForest | Early1:ALL | Early1:ALL | Optional1 | 0.0030 |
| FloodForest | Early1:ALL | Early1:ALL | Optional2 | 0.0100 |
| FloodForest | Early1:ALL | Early1:ALL | ReplacementFire | 0.0010 |
| FloodForest | Early1:ALL | Early1:ALL | SurfaceFire | 0.0050 |
| FloodForest | Late1:CLS | Early1:ALL | Optional1 | 0.0030 |
| FloodForest | Late1:CLS | Early1:ALL | ReplacementFire | 0.0010 |
| FloodForest | Late1:CLS | Early1:ALL | Wind/Weather/Stress | 0.0040 |
| FloodForest | Late1:CLS | Late1:CLS | SurfaceFire | 0.0050 |
| FloodForest | Late1:CLS | Late1:OPN | MixedFire | 0.0020 |
| FloodForest | Late1:CLS | Late1:OPN | Optional2 | 0.0100 |
| FloodForest | Late1:CLS | Late1:OPN | Wind/Weather/Stress | 0.0067 |
| FloodForest | Late1:OPN | Early1:ALL | Optional1 | 0.0030 |
| FloodForest | Late1:OPN | Early1:ALL | ReplacementFire | 0.0010 |
| FloodForest | Late1:OPN | Early1:ALL | Wind/Weather/Stress | 0.0040 |
| FloodForest | Late1:OPN | Late1:CLS | AltSuccession | 1.0000 |
| FloodForest | Late1:OPN | Late1:OPN | MixedFire | 0.0020 |
| FloodForest | Late1:OPN | Late1:OPN | Optional2 | 0.0100 |
| FloodForest | Late1:OPN | Late1:OPN | SurfaceFire | 0.0050 |
| FloodForest | Late1:OPN | Late1:OPN | Wind/Weather/Stress | 0.0067 |
| FloodForest | Late2:CLS | Early1:ALL | Optional1 | 0.0030 |
| FloodForest | Late2:CLS | Early1:ALL | ReplacementFire | 0.0010 |
| FloodForest | Late2:CLS | Early1:ALL | Wind/Weather/Stress | 0.0040 |
| FloodForest | Late2:CLS | Late2:CLS | SurfaceFire | 0.0050 |
| FloodForest | Late2:CLS | Late2:OPN | MixedFire | 0.0020 |
| FloodForest | Late2:CLS | Late2:OPN | Optional2 | 0.0100 |
| FloodForest | Late2:CLS | Late2:OPN | Wind/Weather/Stress | 0.0067 |
| FloodForest | Late2:OPN | Early1:ALL | Optional1 | 0.0030 |
| FloodForest | Late2:OPN | Early1:ALL | ReplacementFire | 0.0010 |
| FloodForest | Late2:OPN | Early1:ALL | Wind/Weather/Stress | 0.0040 |
| FloodForest | Late2:OPN | Late2:CLS | AltSuccession | 1.0000 |
| FloodForest | Late2:OPN | Late2:OPN | MixedFire | 0.0020 |
| FloodForest | Late2:OPN | Late2:OPN | Optional2 | 0.0100 |
| FloodForest | Late2:OPN | Late2:OPN | SurfaceFire | 0.0050 |
| FloodForest | Late2:OPN | Late2:OPN | Wind/Weather/Stress | 0.0067 |
| FloodForest | Mid1:CLS | Early1:ALL | Optional1 | 0.0030 |
| FloodForest | Mid1:CLS | Early1:ALL | ReplacementFire | 0.0010 |
| FloodForest | Mid1:CLS | Early1:ALL | Wind/Weather/Stress | 0.0040 |
| FloodForest | Mid1:CLS | Mid1:CLS | SurfaceFire | 0.0050 |
| FloodForest | Mid1:CLS | Mid1:OPN | MixedFire | 0.0020 |
| FloodForest | Mid1:CLS | Mid1:OPN | Optional2 | 0.0100 |
| FloodForest | Mid1:CLS | Mid1:OPN | Wind/Weather/Stress | 0.0067 |
| FloodForest | Mid1:OPN | Early1:ALL | Optional1 | 0.0030 |
| FloodForest | Mid1:OPN | Early1:ALL | ReplacementFire | 0.0010 |
| FloodForest | Mid1:OPN | Early1:ALL | Wind/Weather/Stress | 0.0040 |
| FloodForest | Mid1:OPN | Mid1:CLS | AltSuccession | 1.0000 |

| | | | | |
|---|---|---|---|---|
| FloodForest | Mid1:OPN | Mid1:OPN | MixedFire | 0.0020 |
| FloodForest | Mid1:OPN | Mid1:OPN | Optional2 | 0.0100 |
| FloodForest | Mid1:OPN | Mid1:OPN | SurfaceFire | 0.0050 |
| FloodForest | Mid1:OPN | Mid1:OPN | Wind/Weather/Stress | 0.0067 |

| Propn | Age Reset | TST Min |
|---|---|---|
| 1.0000 | No | |
| 1.0000 | Yes | |
| 1.0000 | No | |
| 1.0000 | Yes | |
| 1.0000 | No | |
| 1.0000 | Yes | |
| 1.0000 | Yes | |
| 1.0000 | Yes | |
| 1.0000 | No | |
| 1.0000 | No | |
| 1.0000 | No | |
| 1.0000 | No | |
| 1.0000 | Yes | |
| 1.0000 | Yes | |
| 1.0000 | Yes | |
| 1.0000 | No | 20 |
| 1.0000 | No | |
| 1.0000 | No | |
| 1.0000 | No | |
| 1.0000 | No | |
| 1.0000 | Yes | |
| 1.0000 | Yes | |
| 1.0000 | Yes | |
| 1.0000 | No | |
| 1.0000 | No | |
| 1.0000 | No | |
| 1.0000 | No | |
| 1.0000 | Yes | |
| 1.0000 | Yes | |
| 1.0000 | Yes | |
| 1.0000 | No | 20 |
| 1.0000 | No | |
| 1.0000 | No | |
| 1.0000 | No | |
| 1.0000 | No | |
| 1.0000 | Yes | |
| 1.0000 | Yes | |
| 1.0000 | Yes | |
| 1.0000 | No | |
| 1.0000 | No | |
| 1.0000 | No | |
| 1.0000 | No | |
| 1.0000 | Yes | |
| 1.0000 | Yes | |
| 1.0000 | Yes | |
| 1.0000 | No | 20 |

| | |
|---|---|
| 1.0000 | No |
| 1.0000 | No |
| 1.0000 | No |
| 1.0000 | No |

# Attachment 04

Spectrum Coefficients for YoungGap creation

**Spectrum Coefficients for YoungGap creation**

The output YoungGaps was created to model background levels of disturbance on unmanaged lands, and young forest created by burning prescriptions designed to create young forest.

**YoungGap production on unmanaged lands**
The assumptions modelled are that within any unmanaged forest type, across the forest, there will be a constant proportion of those lands that have been disturbed by insects, disease, blowdown or other disturbance, and are in a young-forest state. At a finer scale, a patch that has been disturbed will eventually grow back into a closed state, but elsewhere within that forest type, new disturbance will create new young-forest openings.

The table below shows the per-acre coefficients, by forest type, used to calculate the amount of YoungGap created on each acre of unmanaged land. The best way to think of these coefficients is to imagine a large block of a given forest type: for type 08, dry oak, the coefficient of 0.005 means that for every 1000 acres of unmanaged dry oak, you will find a total of 5 acres of those lands in a disturbed, young-forest state. Over time, those acres will become closed and be replaced by other disturbed acres.

| Forest types | Acres of YoungGap / acre of forest |
|---|---|
| 04, 07 | 0.0075 |
| 03 | 0.0075 |
| 01, 05 | 0.005 |
| 08 | 0.005 |
| 11, 12 | 0.006 |
| 06 | 0.006 |
| 10 | 0.006 |
| 09 | 0.007 |
| 02 | 0.001 |

***Source: The Gap Analysis (posted on the website) was used as the basis of information for these coefficients. This information was considered the most relevant and current information about the current state and likely future state of the forest. There is great uncertainty about the likely future forest because the state of this forest has been largely disturbed by human intervention over most of the area within the past 100 years. Since NRV is based on only natural disturbances, with no human intervention, and over 1000 year period, the direct assumptions used in NRV would need to be examined carefully before applying it to future forest conditions. While Spectrum used a 200 year planning horizon, the Ecological Sustainability Evaluation of ecosystem used a 50 year planning horizon because the uncertainty of likely futures increases greatly with time.***

**YoungGap production by management**
The prescription 'Burning for Young Forest creation' models prescribed burning intended to maintain forest composition and create some openings. This prescription can be applied on seven forest types. When applied, lands will be burned every decade. The prescription can be initiated in the first, second or third decade. When first applied, the number of openings created is slightly lower than in subsequent periods.

| Forest Types | Acres of YoungGap/acre treated – first treatment | Acres of YoungGap/acre treated – subsequent treatments |
|---|---|---|
| 04, 07 | 0.06 | 0.1 |
| 03, 06 | 0.03 | 0.05 |
| 05, 09 | 0.01 | 0.01 |
| 08 | 0.03 | 0.05 |

**Minimum Level allocations and Regen Acres by Alternative**

Source : Spectrum summary tables

*The amount of natural disturbance was calculated on the minimum level acres. These are the acreages that have no active management scheduled in the Spectrum model. Tier 1 has about ¾ of the forest with no active management, whereas, Tier 2 has less than ½ forest with no active management. But, active management includes all possible activities, including prescribed fire, intermediate treatments, and not*

| | | Decade | | | | | Ave |
|---|---|---|---|---|---|---|---|
| Alt | | D1 | D2 | D3 | D4 | D5 | D6 - D20 |
| AltDT2 | RegenAcre | 35,000 | 31,000 | 30,999 | 31,000 | 31,000 | 31,049 |
| AltDT1 | RegenAcre | 11,641 | 12,000 | 11,999 | 12,000 | 12,000 | 12,000 |
| AltCT2 | RegenAcre | 35,007 | 31,004 | 30,997 | 30,998 | 30,999 | 31,267 |
| AltCT1 | RegenAcre | 12,002 | 12,001 | 12,001 | 11,999 | 11,999 | 12,001 |
| AltBT2 | RegenAcre | 34,999 | 30,996 | 31,001 | 30,996 | 31,000 | 31,000 |
| AltBT1 | RegenAcre | 11,593 | 11,999 | 12,001 | 11,999 | 11,999 | 11,999 |
| AltA | RegenAcre | 6,498 | 6,497 | 6,497 | 7,000 | 6,999 | 6,999 |
| | | | | | | | |
| | | Decade | | | | | Ave |
| Alt | | D1 | D2 | D3 | D4 | D5 | D6 - D20 |
| AltDT2 | Minimum Level | 414,437 | 414,506 | 414,556 | 414,845 | 415,327 | 415,689 |
| AltDT1 | Minimum Level | 793,909 | 792,988 | 793,118 | 793,805 | 795,252 | 796,960 |
| AltCT2 | Minimum Level | 500,694 | 500,096 | 500,198 | 500,676 | 501,591 | 502,707 |
| AltCT1 | Minimum Level | 791,516 | 790,312 | 790,413 | 791,075 | 792,495 | 794,560 |
| AltBT2 | Minimum Level | 408,051 | 407,952 | 408,032 | 408,337 | 408,728 | 409,251 |
| AltBT1 | Minimum Level | 793,071 | 792,070 | 792,218 | 792,925 | 794,322 | 796,100 |
| AltA | Minimum Level | 842,079 | 842,096 | 842,097 | 842,097 | 842,097 | 842,097 |
| | | | | | | | |
| | | Decade | | | | | Ave |
| Alt | | D1 | D2 | D3 | D4 | D5 | D6 - D20 |
| AltDT2 | YoungGaps | 2,670 | 3,065 | 3,080 | 3,087 | 3,089 | 3,089 |
| AltDT1 | YoungGaps | 5,630 | 6,746 | 7,370 | 7,688 | 7,688 | 7,688 |
| AltCT2 | YoungGaps | 3,248 | 3,710 | 3,725 | 3,726 | 3,726 | 3,726 |
| AltCT1 | YoungGaps | 5,510 | 6,876 | 7,436 | 7,575 | 7,575 | 7,575 |
| AltBT2 | YoungGaps | 2,722 | 3,181 | 3,211 | 3,229 | 3,232 | 3,232 |
| AltBT1 | YoungGaps | 5,649 | 6,971 | 7,509 | 7,685 | 7,685 | 7,685 |
| AltA | YoungGaps | 4,500 | 4,517 | 4,518 | 4,518 | 4,518 | 4,518 |

*just regeneration. The amount of Regeneration Acres are shown for the alternatives because these activities are used to create young forest.*

**Constraints on Tier 2**

Refer to Appendix D: Table 15: Tier 2 Objectives for Alternatives B, C, D

Young Forest + Young Gaps must be at least 60000 in periods 2 to 20

Young Forest + Young Gaps must be at least 57000 in periods 1 to 1

Acres receiving regeneration cuts cannot be more than 35,000 acres in periods 1 to 20

Upper Limit Alt B,C,D: Period 1

*This constraint is binding in the first planning period for the action alternatives. Since the starting point of young forest is fairly low, there is enough capacity to handle regen increases in the first planning period*

Acres receiving regeneration cuts must be at least 31,000 in periods 1 to 20

Lower limits Alt B,C : Period 2 to 20

Lower limit Alt D: Periods 1-14; 16-20

*This constraint is binding. The model was bounded to meet the regeneration harvests of 32,000 acres by within bounds of 31,000 to 35,000 acres. This constraint hits to lower limit—wants to go lower in periods 2-20 ---most likely due to the next constraint, as follows.*

Young Forest + Young Gaps cannot be more than 90000 acres in periods 1 to 20:

Upper Limit Alt B: Period 2-20

Upper Limit Alt C: Period 3-20

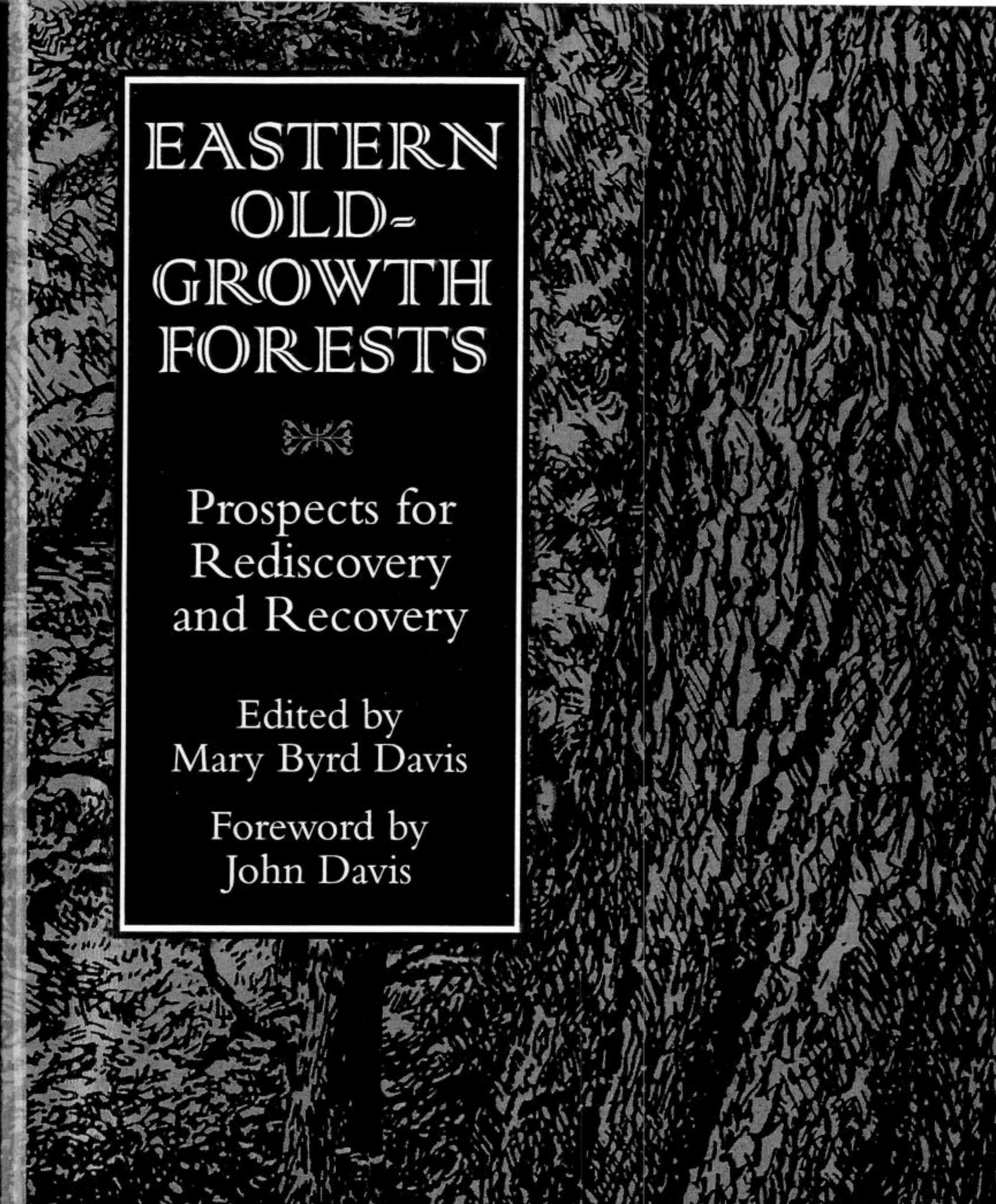
Upper Limit Alt D: Period 3- 20

*This constraint is binding. If young gaps were increased in periods 2 and beyond in Alt B and periods 3 and beyond in Alts C and D, then the constraints would need to be raised above 90,000 acres of young forest+ young gaps to achieve plan objectives.*

*Or, if the constraints were frozen at 90,000 acres of young forest + young gaps, and the amount of young gaps were increased in periods 2 and beyond, then fewer regen acreages would go into solution. That would involve changing the other constraints above for the minimum amount of regeneration of 31,000 ac.*

Attachment 05

# Biodiversity in the Herbaceous Layer and Salamanders in Appalachian Primary Forests



# EASTERN OLD-GROWTH FORESTS

## Prospects for Rediscovery and Recovery

Edited by
Mary Byrd Davis

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Chapter 4

# Biodiversity in the Herbaceous Layer and Salamanders in Appalachian Primary Forests

Albert J. Meier, Susan Power Bratton, and David Cameron Duffy

The southern Appalachians are considered one of the centers of forest diversity in the United States. A person entering a moist, uncut, primary cove hardwood forest in the spring will encounter a spectacular show of vernal wildflowers. These extraordinary displays lure thousands of tourists to the southern Appalachians every year. The ground often appears to be carpeted in a tapestry of whites, blues, reds, and yellows. More discerning visitors may note the exceptional species diversity of these displays. Duffy and Meier (1992) described stands in primary cove hardwood forests where 10 to 14 different species of spring flora occur in each square meter. A single hectare may contain thousands of large-flowered trilliums *(Trillium grandiflorum),* wake robins *(Trillium erectum),* yellow trilliums *(Trillium luteum),* Vasey's trilliums *(Trillium vaseyi),* Dutchman's breeches *(Dicentra cucullaria),* spring beauties *(Claytonia caroliniana),* trout lilies *(Erythronium americanum),* hepaticas *(Hepatica acutiloba),* windflowers *(Thalictrum thalictroides),* and larkspurs *(Delphinium tricorne).*

If visitors look closer still, particularly in the evening, they may observe salamanders, the most abundant vertebrate denizens of this region (Hairston 1987). Petranka, Eldridge, and Haley (1993) report that salamanders typically number one to two individuals per square meter. Meier and Bratton (in press) found six species in a single 25 x 25 meter plot, including the brilliantly striped Yonahlossee salamander *(Plethodon yonahlossee),* the southern redback salamander *(Plethodon serratus),* and the salamander-eating Blue Ridge Spring salamander *(Gyrinophilus porphyriticus danielsi).*

Both salamanders and vernal wildflowers are groups of organisms that attain exceptional abundance and diversity in the southern Appalachians. Therefore, the response of these groups to forest management in this region is particularly important for both local and global biodiversity. Vernal herbs and salamanders share a set of characteristics including dependence on moist environments, long generation times, low reproductive rates, slow dispersal, and an association with mortality of mature canopy trees that cause them to show similar response to forest management.

## Definitions

Duffy and Meier (1992) provide the definitions that we will use for primary, secondary, and mature forests: ". . . we use *primary* to describe forests that have never been clearcut and that have little or no evidence of past human activity. Such forests may have been grazed, they may have experienced limited exploitation of valuable tree species, and their floors may have been burned by Amerinds and European pioneers. Primary forests contain abundant downed timber in varying states of decay, standing dead trees, and live trees in a range of sizes. *Secondary* forests are those that have developed after the previous forest was extensively logged or clearcut. We use *mature* to refer to secondary forests that have existed longer than the normal harvesting rotation practiced by foresters on that particular forest type."

## History

Why are there only a few remnants of primary forest left in the southern Appalachians? Native Americans began clearing parts of the forests perhaps 12,000 years ago (Dickens 1976). Native American settlement appears to have been concentrated in the floodplains and had little permanent effect. Settlement by Euro-Americans began in the 18th century and increased the extent and permanence of forest clearing (Lambert 1958). Timber harvesting for industrial purposes logged much of the forests of the southern Appalachians between 1880 and 1920 (Frothingham 1931). Catastrophic fires frequently followed the logging (Ayres and Ashe 1905). In 1911, the Weeks Act authorized federal purchase of forests for the protection of watersheds. Today, approximately two-thirds of the region is forested, with one-fifth of this land managed as national forests (Boone and Aplet 1994). In excess of 500,000 additional forested acres are within Great Smoky Mountains National Park.

How much primary growth is left in the southern Appalachians? Most of the forests in the region are even-aged and less than 100 years old. However, the southern Appalachians contain one of the largest concentrations of primary forests east of the Mississippi River (Davis 1993). Stands that are 100 years or older constitute approximately 480,000 acres of the 11.3 million acres of timber-base land in the southern Appalachian region of Virginia, Georgia, North Carolina, and South Carolina (Boone and Aplet 1994). Doubtless this number will be adjusted as the Forest Service data on which this survey was based are improved. These 100-plus-year stands are considered potentially as primary, though many may prove to be older secondary forests or simply misidentified. An additional 100,000 acres of forests considered to be high in primary attributes exist within the boundaries of Great Smoky Mountains National Park (Houk 1993). The vast majority of old-growth acreage appears to lie within the federal lands (Boone and Aplet 1994).

The southern Appalachians are a region of exceptional plant diversity for the temperate zone. Well over 2,000 species of native vascular plants are known from this region. One of the more conspicuous components of southern Appalachian forests, especially mesic sites, is the vernal herbaceous community (Braun 1950). The southern Appalachians are also considered the center of salamander diversity on earth (Petranka, Eldridge, and Haley 1993). Boone and Aplet (1994) report 54 species of salamanders in the region. Salamanders comprise the largest portion of the vertebrate predator biomass of these forests (Hairston 1987).

## Primary Forests Vs. Secondary Forests

Prior to European settlement, the landscape of the region was dominated by forests (Bartram 1792). Pickett and White (1985) note that anthropogenic disturbance in the form of agriculture and logging have interrupted the gap dynamics of the forest and led to the creation of uniform stands of successional overstories above understories dominated by shade-tolerant species.

Perhaps a short description of the disturbance regime will help clarify the conditions under which most of these species have survived since the Pleistocene. This regime is important because disturbances help regulate the composition, structure, and function of forests (Pickett and White 1985). Fire in the primary cove hardwoods of the southern Appalachians appears to be infrequent. Harmon, Bratton, and White (1983) found an historic fire-return frequency for Great Smoky Mountains National Park as a whole of 840 years for human-caused fires and 30,000 years for lightning-caused fires. Fires of both types are extremely rare above 1,000 meters (Harmon, Bratton, and White 1983). Goodwin (1977) suggests that Native Americans frequently set fires prior to Euro-American settlement. Euro-Americans often burned sub-mesic and relatively xeric forests below 1,500 m (Ayres and Ashe 1905). Lorimer (1976) found no evidence of fire in trees that he cored in the Poplar Grove of

Joyce Kilmer Memorial Forest during the past 300 years; furthermore, he found no evidence of charcoal in the upper layers of soil. Wind disturbance probably plays a greater role than fire. Lorimer suggests that blowdowns may have eliminated as much as 15% of the canopy within the Poplar Grove during a few peak disturbance decades.

Gap formation resulting from tree falls is the most common natural form of canopy disturbance in moist primary forests (Runkle 1982). Runkle (1981, 1982) examined gap size and frequency in a number of primary mesic forest stands in the southern Appalachians, including stands in Great Smoky Mountains National Park, Joyce Kilmer, and Walker Cove. Gap size ranged from 1 to 1,490 square meters, with a geometric mean of 65 square meters. New gaps formed at an average rate of 1% of land surface area per year. As a result of the disturbance, primary Eastern forests usually have irregular all-age structures (Lorimer 1976).

It is important to understand the influences of the present even-aged management on the diverse flora and fauna, including salamanders, of the southern Appalachians—for three reasons. First, much of the forested landscape there is now occupied by even-aged second growth. Second, current forest management plans include further fragmentation and additional harvests leading to even-aged stands even on some of the forest currently identified as old growth. Finally, it is assumed by many that maturing secondary forests will adequately replace primary stands. This chapter challenges the validity of this last assumption.

The scientific literature includes several studies attempting to detect recovery of forest understories following major disturbance. In hardwood stands in New Brunswick, Canada, MacLean and Wein (1977) found little evidence of recovery of late-successional herbaceous species several decades after canopy opening. Flaccus (1959) found that, following landslides in the White Mountains of New Hampshire, 72-year-old herb communities were similar to older (200+ years) forests, but a number of primary species were still absent from the 72-year site. Brewer (1980), working in old growth in Michigan, concluded that the herbaceous community was still recovering from a major disturbance event 150 years prior. Studies in Great Britain indicate that recovery of forest herbs after an area has been used for agriculture may take centuries (Peterken and Game 1984). Bratton and Miller (1994) found that understory plants on Cumberland Island, Georgia, were severely reduced following agricultural disturbance even after a century, though the overstories had appeared to recover. Similarly, salamanders suffer profound and long-term negative effects after logging. These effects have been observed both in the Pacific Northwest (Bury 1983 and Welsh 1990) and in the Eastern U.S. (Bennett, Gibbons, and Glanville 1980; Raymond and Hardy 1991).

Vernal herbaceous richness in one-square-meter plots was consistently higher in primary cove hardwood forests in the southern Appalachian Mountains than in comparable secondary forests (Duffy and Meier 1992; Meier, Bratton, and Duffy, in press). In 10 paired primary and secondary sites, species richness in 1 $m^2$ quadrants averaged 11.2 species on primary sites and 6.9 on secondary sites. We found no evidence that cover or richness of vernal herbs recovers even after almost nine decades (Duffy and Meier 1992). This suggests three possibilities: (1) that recovery is so slow or variable among sites that 90 years is insufficient time to detect it; (2) that such forests will never recover to match remnant primary forests, because they have reached an alternative lower diversity state, perhaps because climatic conditions are different today than when the forests became established; or (3) that herbaceous plants depend on gap-phase dynamics caused by the death of trees, so that recovery must await the growth, death, and decomposition of the trees of the secondary forest. Whatever the mechanism, herbaceous understory communities in the mixed-mesophytic forests of the Appalachians appear unlikely to recover within the present planned logging cycles of 40 to 150 years, suggesting continuing loss of diversity of understory herbaceous plants.

We have found no species of vernal herbs that are only in primary forests; however, many species occur more frequently in primary forests and a few of these occur much more frequently there. We have not found any of these to be ubiquitous across all southern Appalachian primary forests. Species that appear much more frequently in primary forests include dwarf ginseng *(Panax trifolium)* and *Cymophyllus fraserianus* in Great Smoky Mountains National Park, and Goldie's woodfern *(Dryopteris goldiana)* in the Toecane District of Pisgah National Forest.

We would like to suggest the existence of five ecological mechanisms for reducing or limiting species richness per plot (alpha diversity) of vernal herbs and salamanders in logged stands, three of which may also account for the slow recovery of some species: (1) Logging directly reduces populations of salamanders and rarer herbs; (2) populations of forest-floor species are further reduced during the successional stages following logging, either by inability to adapt to changed microclimate or, in the case of herbs, by competition with r-selected species ("weedy" species with high reproductive and dispersal rates), which are better dispersers and better able to tolerate desiccation and increased radiation; (3) forest-floor herbs have slow growth and both these herbs and salamanders have low reproduction rates, thus population densities increase slowly; (4) many forest-floor herbs and salamanders are slow dispersers, thus they are slow to reoccupy suitable habitat once locally extirpated or greatly reduced in population numbers; and (5) secondary forests may have less than optimal conditions for forest-floor herbs and salamanders because microhabitats on the forest floor, including well-decayed large logs and gaps, may be temporarily eliminated by interruption of gap-phase dynamics.

## Mechanism 1: Logging-Caused Diversity Loss

Disturbance that accompanies logging negatively impacts salamanders and vernal herbs. The harvesting systems and the occurrence of associated disturbances, such as burial under slash, will determine the degree to which the forest-floor flora and salamanders are affected.

The results from even a small recent clearcut demonstrate early loss of vernal herbs (Meier, Bratton, and Duffy, in press). We find an initial loss of vernal herbs soon after clearcutting followed by a lack of recovery, if not continuing losses of vernal herbs through age 87 (Duffy and Meier 1992). This agrees with the temporal sequence of vernal herb diversity after the logging of second-growth stands predicted by Bormann and Likens (1979). However, unlike Bormann and Likens's prediction, we find that diversity of vernal herbs is higher in primary forest than in recently clearcut stands (Duffy and Meier 1992). Petranka, Eldridge, and Haley (1993) examined clearcut stands 10 years or less old and concluded that salamander abundance was reduced by 75% or more following clearcutting, and species per plot were reduced by about half.

Petranka, Brannon, and Hopey (in press) examined the influences of intensive timber management on southern Appalachian salamander communities. Their comparison of clearcuts with mature forests led them to conclude that clearcuts almost completely eliminate terrestrial salamander populations. Aquatic and semi-aquatic salamanders were also severely reduced in abundance. They conclude that more than 120 years may be required for salamander populations to recover after disturbance. Meier and Bratton (in press) obtained similar results, finding a correlation between stand age and both number of salamander species detected per plot and number of salamander individuals detected per plot. The highest number of species per plot was found in the one primary stand that they examined.

## Mechanism 2: Stress, Competition, and Herbivory

Even if logging is carefully conducted and few herb populations are damaged in the process, removal of trees still opens the forest canopy and initiates succession. In the Eastern United States, "high-grading" (the removal of a few exceptionally valuable trees) or careful selective cutting may have effects similar to gap-phase succession (Meier, Bratton, and Duffy, in press). However, clearcutting may allow more disturbance-tolerant genera to increase in frequency and cover, displacing populations of less disturbance-tolerant forest-floor herbs.

Community organization for spring ephemerals in relatively undisturbed forest is based on a mixture of biotic and abiotic factors, including competition for light, pollinators, and nutrients; species-specific microhabitat preferences; canopy species; and stand history (e.g., Bratton 1976; Muller 1978; Hicks 1980; Motten, Campbell, and Alexander 1981; Givnish 1982; Beatty 1984; Rogers 1985; and Motten 1986). Together these studies suggest that vernal species may be eliminated by competition for light and nutrients from taller herbs and shrubs. Further, some vernal herbs occupy very specific types of microhabitats on the forest floor, and once displaced may not be able to survive on other, less suitable sites.

Following clearcutting in a watershed in the southern Appalachians, moisture contents of the O horizons of the soil were reduced by as much as half; however, moisture in the A horizon increased (Swank and Vose 1988). Perhaps more detrimental, mean monthly surface temperature was elevated by as much as 10° C. Daily maximum temperatures sometimes exceeded 54° C in summer. Such temperatures can be hazardous to both herbs and salamanders. Ash (1988) found an increase in bare soil in clearcuts, and Raphael (1988) found a decrease of litter in clearcuts. Loss of litter may expose shallow roots, desiccate vernal herbs, and decrease cover for salamanders. Many forest herbs are not adapted to making photosynthetic use of the greater light availability that results from the removal of the canopy (Hicks and Chabot 1985). Increased temperatures in summer lead to increased metabolic cost. Many vernal herbs lack the ability to sustain such cost and may experience mortality or reproductive failure (Nault and Gagnon 1993). Petranka, Eldridge, and Haley (1993), Petranka, Brannon, and Hopey (in press), and Spotila (1972) point out that most salamanders require moist environments to avoid desiccation. Petranka, Eldridge, and Haley (1993) also point out the sensitivity of southern Appalachian salamanders to increases in soil surface temperature following intensive logging.

In the Susquehanna River gorge, Bratton, Hapeman, and Mast (1994) found that on 25 x 50 meter plots, early successional old fields had fewer vernal herb species than did stands with pole-sized trees. These in turn had fewer species than mid-successional stands, which had fewer species than mature stands. The low frequencies of species such as northern nodding trillium *(Trillium flexipes)* and squirrel corn *(Dicentra canadensis)* in the pole-sized stands also indicate that some herbaceous species have been nearly extirpated, either by the disturbance that opened the canopies or by subsequent successional processes. It is important to recognize that some herb species occur much less frequently in younger stands than do others, and that the ecological tolerances of the herbs may contribute to this.

Open successional sites and the initial stages of forest regrowth may also be more prone to browsing by white-tailed deer *(Odocoileus virginianus)* (Cottam and Curtis 1956; Alverson, Waller, and Solheim 1988; Meier, Bratton, and Duffy, in press). This problem may become more severe with increasing forest fragmentation and white-tailed deer populations.

## Mechanism 3: Low Reproduction Rates and Slow Growth

A third reason that vernal herb diversity and abundance may remain low, even decades after logging, is that herbaceous plants of late-successional forests mature slowly—some species of vernal herbs take a decade or more from seed to first flowering (Curtis 1943, Bierzychudek 1982a). Likewise, Hairston (1983) and Hairston et al. (1992) indicate that many salamanders have long generation times, and Petranka, Brannon, and Hopey (in press) suggest that long generation times may slow salamander recovery in secondary forests. Upon reaching maturity, many vernal herb species produce few seeds. Many species also demonstrate slow rates of growth. Growth as little as 1 cm $yr^{-1}$ has been reported from a wide variety of late-successional forest herbs at sites in the northern United States and Canada (Sobey and Barkhouse 1977, Whitford 1951). Meier, Bratton, and Duffy (in press) suggest that growth rates in the South are similar to or slower than northern rates, rather than faster. Second, slow vegetative growth of late-successional herbs may reflect a K-strategy of restrained investment in reproduction and growth (Gadgil and Solbrig 1972, Bierzychudek 1982a) and increased allocation of resources to energy and nutrient storage (Newell and Tramer 1978) in an environment where competition is severe for soil nutrients (Rogers 1985) or for light (Givnish 1982). Such competition may be more a factor of successional state than of latitude; but studies of northern old growth have not been undertaken.

Given a time lag of up to a decade from seed to first flowering for many vernal species and limited seed production of late-successional understory herbaceous plants, slow vegetative growth should contribute to slow recovery following logging. Meier, Bratton, and Duffy (in press) found that for large-flowered trillium, wake robin, and yellow trillium, populations in secondary forest, where they occurred, were significantly lower in density than populations in primary forest. This suggests that slow population growth is a factor leading to low densities of trillium in secondary forests.

## Mechanism 4: Limited Spread and Slow Dispersal

Understory herbaceous plants exhibit a variety of life-history strategies, but many are functionally clonal (Whitford 1949, Harper 1977) and long-lived (Whitford 1951, Cook 1983). Clonal species may be slow to reoccupy large areas. Whitford (1949) found that some herbaceous species became more evenly distributed in later successional stages. He suggested, without direct measurement, that patches of such species are larger in late succession. He suggested that reproductive strategies determined spatial distribution: Clonally reproducing species became less patchy with apparent increases in stand age, whereas species with widely dispersed seeds showed no change in distribution. Primary sites appear to contain networks of overlapping clonal patches of different species (cf. Whitford 1949). Parts of patches may die or be displaced by other species so that remnants of the original clones become noncontiguous. Recolonization of disturbed sites is likely to be slow because late-successional herbaceous species tend to spread by clonal growth or by gravity- or ant-dispersed seeds (Beattie and Culver 1981), limiting the rate at which deforested areas can be colonized. In addition, single species of ants may be the sole agents of seed dispersal for some species (Don Waller, University of Wisconsin, Madison). Matlack (in press) has reported that rates of seed dispersal can be extremely slow. For example, he found that the rate of dispersal of black cohosh *(Cimicifuga racemosa)* was effectively zero meters per year.

Other species of vernal herbs are dispersed by gravity—for example, dwarf ginseng (Philbrick 1983). Meier, Bratton, and Duffy (in press) found that dwarf ginseng dispersed its seeds within 25 centimeters of the mother. Given the slow rates of dispersal and the short distances that propagules are dispersed from parent plants, landscape features such as high elevations, dry ridges, roads, and agricultural fields may present impassable barriers to dispersal for these plants.

Petranka, Brannon, and Hopey (in press) and Meier and Bratton (in press) suggest that the slow recovery of salamander populations can be explained in part by extremely slow dispersal of salamanders (Hairston 1983, Hairston et al. 1992). Meier and Bratton (in press) found that forest fragments of less than 10 hectares were depauperate of salamanders and suggest that forest fragmentation may present nearly insurmountable barriers to recolonization of severely disturbed sites.

## Mechanism 5: Habitat Loss and Disruption of Gap-Phase Succession

Differences in physical structure and cover between primary and second-growth understory herbaceous communities may affect the functioning of forest ecosystems. Bratton (1976) found that some species of vernal herbs most commonly root in deep pockets of organic matter or at the base of trees or on fallen logs. Therefore, removal of organic materials, especially logs, may reduce microhabitat availability for vernal herbs. Petranka, Brannon, and Hopey (in press) and Meier and Bratton (in press) found correlations between the number of individual salamanders and salamander species per plot and the availability of well-decayed coarse woody debris. Petranka, Eldridge, and Haley (1993) found a positive correlation between such coarse woody debris and forest maturity.

Logging also modifies the distribution of light on the forest floor. Clearcuts change from intense light to very limited light as succession closes the canopy. Canopy gaps are infrequent in younger successional forests and probably continue to decline in the Appalachians until at least age 80. It may require 150 to 200 years before gap-phase processes are completely reestablished. Tree falls produce not only pits and mounds and fallen logs that provide new microhabitats, but also small areas of elevated but not extreme radiation. Because canopy gaps are partially shaded, they are not as desiccating as open clearcuts, nor are they as likely to be invaded by r-selected species or exotics.

Meier, Bratton, and Duffy (in press) found that *Cimicifuga americana* was more abundant in canopy gaps and that its fruiting was significantly dependent on and positively associated with the presence of gaps. Thus, the reduced gap formation in secondary forests may lead to a lack of recovery or even decline in *C. americana* populations, a phenomenon that may also apply to other gap-dependent species. Moore and Vankat (1986) found that herb cover slowly increased within gaps.

## Management Implications

Meier, Bratton, and Duffy (in press) found no correlation between size of primary stand and mean number of species per square meter. This result suggests that even small remnant primary forest stands are important reserves of vernal herb diversity. Nevertheless, while preservation of small tracts of primary forest appears to be important in maintaining diversity, they may not be adequate to preserve diversity on regional and larger scales. Vernal herbs and salamanders would be slow to recolonize clearcut areas from small remnant primary stands because of slow growth, low rates of reproduction, poor dispersal, loss of suitable habitat, and disruption of gap-phase dynamics.The caveat for forest management is that larger remaining blocks of primary forest should be protected as well as small stands; if only small tracts were left, one could expect a reduction in regional and global diversity.

Because vernal herbs and salamanders demonstrate low rates of recovery (Duffy and Meier 1992; Petranka, Eldridge, and Haley 1993), harvest methods that cause less mortality are preferable; for example, logging methods that mimic natural gap-phase dynamics may be less damaging than clearcutting. Because of the poor dispersal characteristics of many vernal herbs and salamanders, further forest fragmentation caused by the building of logging roads may pose additional barriers to recovery of these organisms. It is also possible that transplantation and active reintroduction of these species may help restore vernal herb and salamander populations of secondary mixed mesophytic forests.

## Summary

Though the ecological effects of a clearcut are influenced by many things, such as the extent and shape of the cut, land contours, and the nature of the surrounding uncut forest, certain general trends can be expected. With canopy removal, nutrients are lost from the ecosystem. Logging equipment inflicts damage on both soil and herbs.

With the canopy removed, temperatures at the soil surface become greatly elevated during the summer, causing mortality of salamanders and shallow-rooted vernal herbs. Many forest herbs cannot make use of the greater light availability that results from canopy removal. When summer comes, increased temperatures lead to vastly increased metabolic cost, which many vernal herbs cannot afford because they are not very photosynthetically active during the hottest portion of the year. Many long-lived perennial herbs show slow population growth rates (Bierzychudek 1982b, Meagher 1982, Kinoshita 1987, Charron and Gagnon 1991, Nault and Gagnon 1993).

A closed-canopy stand begins to develop after about 15 years. This presents an additional problem for herbs that depend upon gaps for reproduction. This shortage of canopy gaps often continues through stand-age 80, and the size and rate of canopy gap formation will not achieve the levels found in primary forests before age 150 to 200 (Bormann and Likens 1979).

Some species benefit from the formation of canopy gaps, pits and mounds, and rotting logs. Canopy gap formation increases light availability, soil moisture, and soil nutrient availability. Canopy gaps, unlike clearcuts, provide a gradient of light intensity increasing from the edge of the gap toward the center. Clearcutting leads to a decrease in both spatial and temporal heterogeneity of the environment within the stand.

By the time canopy gap formation has been reestablished to the levels found in primary forests, many species have been eliminated from the clearcuts. Most vernal species are not adapted for rapid dispersal. In the southern Appalachians, there are many topographic barriers to dispersal. Even if a species becomes established in an area, it is still likely to show low rates of clonal growth and sexual reproduction. Clearcutting of primary mixed mesophytic forests causes mortality of many vernal herbs. Life history characteristics of these species lead to very long recovery periods, if recovery occurs at all.

All of these factors combine to retard recovery of the herbaceous understory in southern Appalachian forests. The low to nonexistent recovery rates observed for vernal forest herbs suggest that a landscape of hypothetically restored old secondary forest may not serve to conserve and restore vernal herb populations. Management plans should include protection of remaining primary mixed mesophytic forests.

The southern Appalachians are a center of diversity for both salamanders and temperate herbaceous flora. The more mesic primary forests of this region contain extraordinary densities and diversities of both salamanders and vernal herbs. Secondary forests of the same type have severely reduced populations and diversities of both. Furthermore, it appears that salamanders and vernal herbs recover slowly, if ever. It seems that the similar responses of these two groups result from a set of similarities among the groups. These similarities include dependence on moist environments, long generation times, low reproductive rates, slow dispersal, and an association with mortality of mature canopy trees. Other taxonomic groups that share the first four characteristics or a dependence on mortality of mature canopy trees may also be primary specialists.

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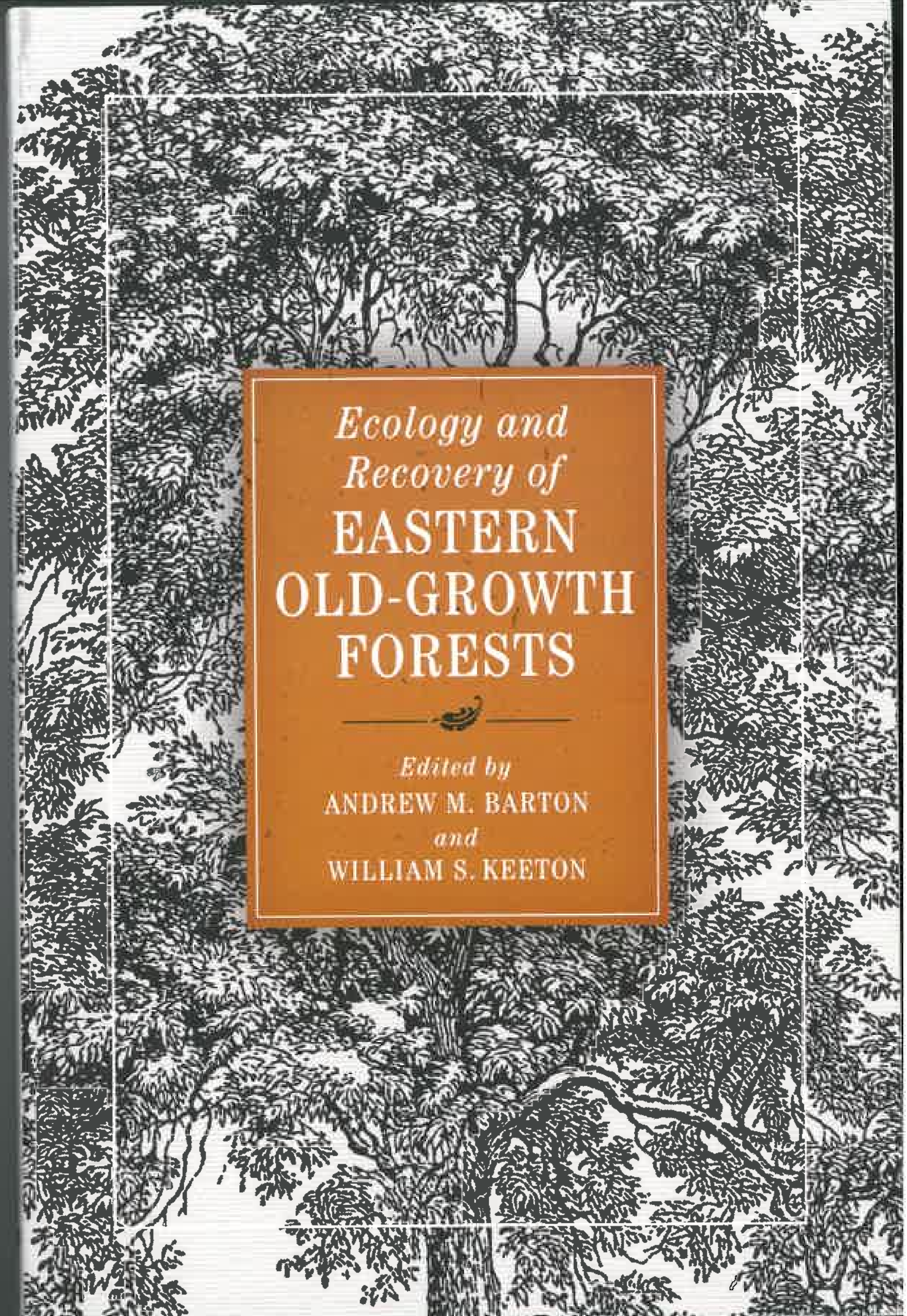
Attachment 06

# Belowground Ecology and Dynamics in Eastern Old-Growth Forests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## Chapter 10

# Belowground Ecology and Dynamics in Eastern Old-Growth Forests

*Timothy J. Fahey*

Eastern old-growth forests possess features that distinguish them from human-disturbed stands, especially in terms of the structure, diversity, and function of the ecosystem. To the forest visitor, the distinctive aboveground structure of the old-growth forest is most visible and striking: towering trees, multiple canopy layers, large snags, and coarse woody debris. Hidden from view is an equally complex belowground world that has largely escaped study by ecologists simply because access and observation are so difficult. Are the complex structures and distinctive function aboveground in eastern old-growth forests mirrored in the soil? In this chapter, I summarize current evidence about features of the belowground dynamics of eastern old-growth forests that are characteristic of these spectacular ecosystems.

As summarized by Burrascano et al. (2013) and in chapters 1, 7, and 11 of this volume, the key structural features that distinguish old-growth forests from younger, second-growth stands are: (1) abundance of large living trees; (2) high volume of coarse woody debris in varying stages of decay; (3) vertical heterogeneity, including large canopy gaps created by the mortality of large trees; (4) pronounced microtopography created by tree uprooting; and (5) species composition dominated by understory tolerant species. What features of belowground forest dynamics would reflect these aboveground characteristics in eastern old-growth forests?

In terms of land-use history in eastern North America, one pervasive anthropogenic effect on belowground dynamics requires special attention: Except in the most rugged and remote landscapes, a period of agricultural activity followed European settlement. The legacy of agricultural activity on forest soils and their properties is profound and persistent, typically much more so than forest harvest. In Europe, for example, Depouey et al. (2002) observed that effects of agricultural land use on forest soil properties persisted for millennia. In northeastern forests, the nitrogen dynamics of postagricultural soils were strikingly different from primary forest more than a century after abandonment and reversion to forest (Compton and Boone 2000). In contrast, after logging, most biogeochemical features of soil recover more quickly, although Latty et al. (2004) were able to detect more subtle but significant differences in soil carbon and nitrogen stocks between mature, postlogging stands compared to virgin forest in the Adirondack Mountains, New York. In this chapter, I will not focus on the belowground legacy of agriculture, which has received considerable attention.

## Overview of the Effects of Features of Old-Growth Forest on Belowground Dynamics

I begin by briefly considering each of the five distinctive aboveground features of old-growth forest, listed earlier, and how they might affect belowground dynamics, especially pedodiversity, the highly variable morphology and other properties of old-growth forest soils.

### *Large and Old Living Trees*

It has long been known that individual trees can profoundly influence soil properties beneath their crowns, including pH, carbon, nitrogen, and base cations (Zinke 1962). The pattern and intensity of this influence will depend on the crown dimensions of individual trees as well as how long the tree lives. One important source of single-tree influence, particularly in humid, eastern broadleaf forests with decurrent crowns (spreading or rounded), is the funneling of precipitation to the base of the tree by "stem flow." This mechanism is less important in excurrent (cone-shaped crowns) conifer forests where rainwater drips from drooping branches. The stem flow effect is further extended belowground by "double-funneling" whereby the roots induce preferential flow of intense rains through soils, bypassing the micropores of the soil matrix and delivering water to deep soil layers (Johnson and Lehman 2006). Another pervasive influence of big trees on soils resulting from tree death is the formation of large gaps and, in the case of windthrow, the formation of pit-and-mound topography.

### *Coarse Woody Debris (CWD)*

Accumulation of dead logs on the forest floor is a defining feature of old-growth forests that influences numerous ecosystem patterns, processes, and functions (Harmon et al. 1986). Of course, most CWD occurs at the aboveground-belowground interface and as such can profoundly influence belowground dynamics. In fact, in some forests, especially in cold boreal zones, a considerable proportion of the CWD actually accumulates within the soil matrix, often as a result of preservation from rapid decay by insulating bryophytes (e.g., mosses). However, a recent summary indicates that buried wood is only a minor component in eastern deciduous forests in part due to limited development of bryophyte cover (Moroni et al. 2015) and also because of the more rapid and complete decay of angiosperm than gymnosperm wood (Cornwell et al 2009).

### *Canopy Gaps*

Death of large, old trees in old-growth forests leads to the formation of large gaps with consequences for belowground dynamics. For example, Dahir and Lorimer (1996) observed that mean gap area was fourfold greater in old-growth than mature northern hardwoods and hemlock stands in upper Michigan. Belowground responses to large gaps are likely to be greater than for small gaps because of the potential to form a "root gap" where few roots of surrounding edge trees immediately colonize the gap (figure 10-1); however, the evidence for formation of root gaps is mixed, as detailed later. Nevertheless, there is some clear evidence for soil nutrient responses to canopy gaps, and the implications for the nutrient balance of eastern old-growth forest landscapes is intriguing. Perhaps gaps contribute to net losses of limiting nutrients (McGee et al. 2007; see nitrogen dynamics section).

### *Microtopography*

Among the most distinctive effects of agricultural land use on forest soils is the elimination of pit-and-mound microtopography. Conversely, the formation of highly developed microtopography is favored in eastern old-growth forests by the uprooting of large trees that are particularly susceptible to windthrow in part because of their tall stature and broad crowns

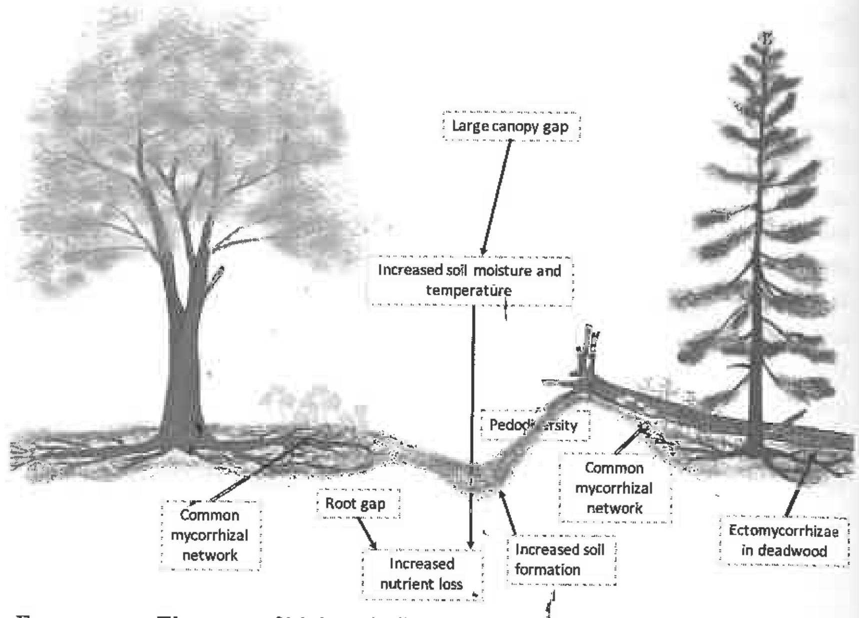
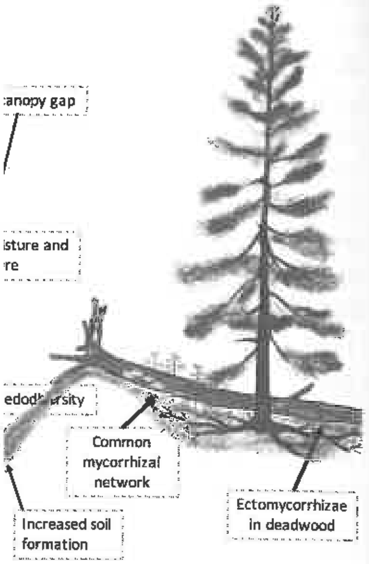



FIGURE 10-1. Elements of high pedodiversity in eastern old-growth forests: blowdown of big trees leads to large canopy gaps and tip-up mounds and pits. The largest gaps may contain "root gaps" in soils that result in nutrient losses as well as renewed soil profile development, especially in pits. Mycorrhizal associations and common mycorrhizal networks may play an important role in tree regeneration in old-growth forests.

(figures 10-1, 10-2). Of course, the pits and mounds formed by big trees are more accentuated and persistent than for smaller trees (Sobhani et al. 2014), contributing to the high pedodiversity observed in eastern old-growth forests (Scharenbroch and Bockheim 2007).

## *Forest Composition*

As noted earlier, soil properties like pH, nitrogen, and base cations can be influenced by individual trees, and species effects at the stand scale also are common. Thus, the composition of eastern old-growth forests, dominated by highly-tolerant understory species, can regulate belowground processes. The spatial dynamics of changes in species composition in old-growth forest may exhibit intriguing self-organization. For example, Frelich et al. (1993) suggested that the formation of a mosaic of discrete patches of

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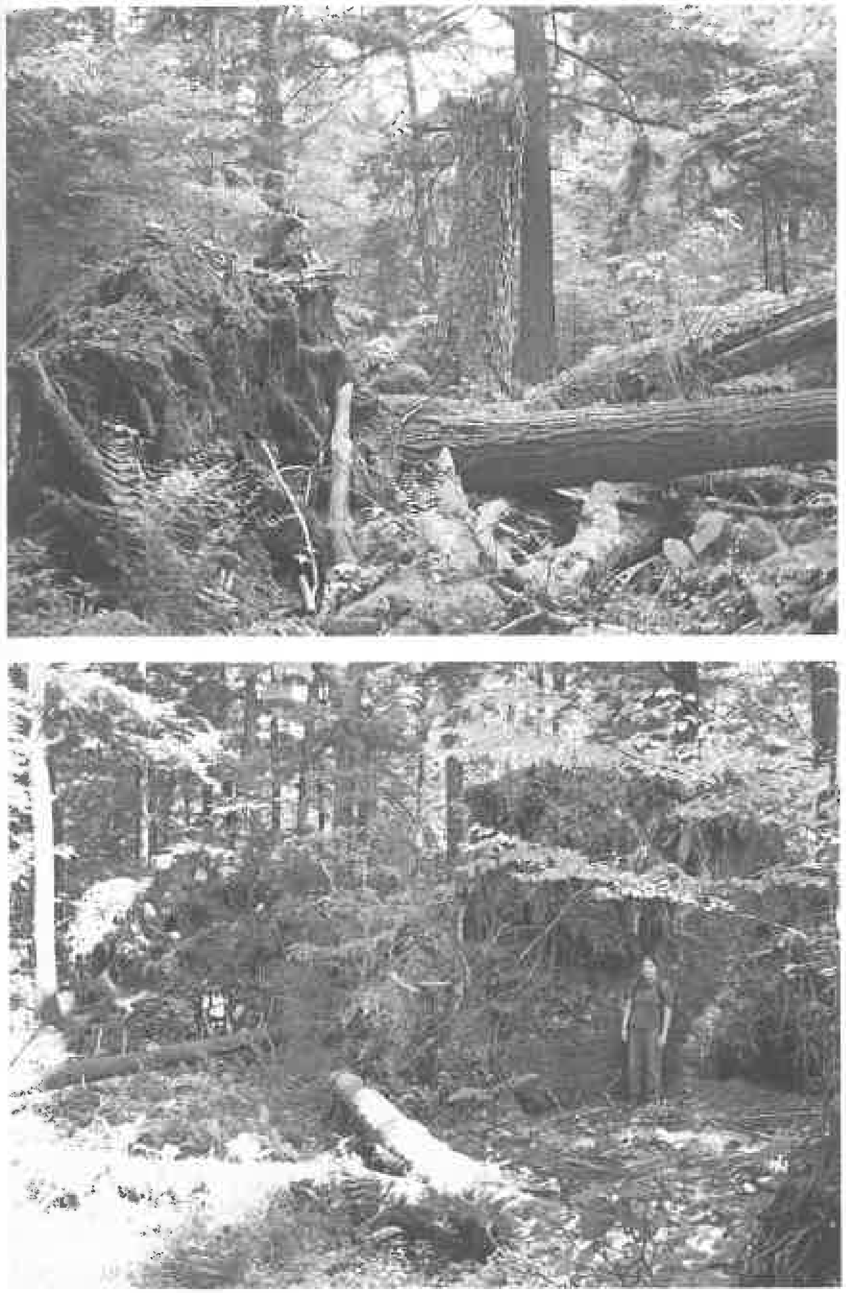

FIGURE 10-2. Two photos showing tip-up mound size and related gap structural complexity in an old-growth hemlock-northern hardwood stand in the Adirondack State Park, New York State. Photo credits: W. S. Keeton.

hardwood (maple) and conifer (hemlock) stands in an old-growth upper Michigan forest resulted from strong negative reciprocal association between these two dominant species, which could further result in distinctive soil chemistry feedbacks (pH, calcium; Fujinuma et al. 2005). Moreover, this sort of pattern also could be reinforced by the mix of tree species characterized by associations with ectomycorrhizal fungi (Pinaceae, Fagaceae, Betulaceae, etc.) versus arbuscular mycorrhizal fungi (Sapindaceae, Rosaceae, Magnoliaceae, etc.). Phillips et al. (2013) suggested that these classes of mycorrhizae can have an overriding effect on carbon-nutrient coupling in temperate forests so that nutrient dynamics are highly dependent on forest composition. Thus, belowground dynamics in eastern old-growth forests are distinct from those in successional stands even though few of these features will be obvious to the casual visitor.

## Seven Key Features of Belowground Dynamics in Eastern Old-Growth Forests

In this section I provide a detailed overview of seven features of the patterns and mechanisms of belowground dynamics of eastern old-growth forests: canopy gap effects, pit-and-mound microtopography, roots and mycorrhizae, soil carbon, nitrogen cycling, terrestrial salamanders, and invasive earthworms.

### *Gaps in Eastern Old-Growth Forests*

As forest stands mature following largescale disturbances like hurricanes, fires, or clear-cutting, in the transition to old-growth status, the overstory canopy may break up as some overstory trees senesce. The death of overstory trees results in canopy gaps, and these tend to be larger in old-growth forests because some of the trees are bigger, causing more collateral damage when they fall. Nevertheless, even in old-growth stands, the mean size of gaps is usually relatively small ($\bar{x}$ = 44 m$^2$; Dahir and Lorimer 1996) except when intermediate-severity disturbance events like microburst windstorms cause more extensive damage (Papaik and Canham 2006). Typical small gaps caused by single-tree deaths can result in increased insolation (i.e, sunlight) and consequently higher surface soil temperatures, but these gaps are usually too small to cause a "root gap" because the horizontal extent of neighboring trees will completely encompass the gap; that is, the root systems of canopy trees extensively overlap (Buttner and Leuschner 1994). Nevertheless, root gaps have sometimes been observed in deciduous forests either as reduced fine root biomass or growth (Bauhus and Bartsch 1996). In some cases, however, fine root growth has been observed to increase in old-growth forest gaps (Battles and Fahey 1996), possibly reflecting increased soil resource availability and increased root growth of advance regeneration. The timing and duration of the gap influence on root growth also varies, but some observations indicate rapid (less than one year) and persistent (several years) effects (Bauhus and Bartsch 1996). In sum, a suite of factors will influence the dynamics of root gaps within canopy gaps, including 1) gap size, 2) size and species of neighboring trees, and 3) abundance of advance regeneration.

The existence of a root gap together with changes in the soil environment (e.g., higher temperature, moisture; figure 10-1) could result in increased soil nutrient availability and possibly consequent nutrient losses in dissolved or gaseous forms. Indeed, Scharenbroch and Bockheim (2007) provided evidence for increased leaching losses in canopy gaps in old-growth northern hardwood forests in upper Michigan, and McGee et al. (2007) noted similar slight increases in Adirondack northern hardwood forest gaps. Especially large nitrogen leaching losses were reported by Ritter and Vesterdal (2006) for gaps in mature Danish beech forests on nutrient-rich soils, suggesting dependence on site fertility (see nitrogen cycling below). Complex interactions between gap formation and coincident pedoturbation was documented in eastern old-growth forests by McGee et al. (2007).

### *Pit-and-Mound Microtopography*

In eastern North America there has been a gradual reduction in the extent of pit-and-mound topography over centuries as a result of agricultural land use, repeated logging, and a decline in the average size of trees, as old-growth forests clearly retain more and larger pits and mounds (Samonil et al. 2010). The principal effect of pit-and-mound formation is to increase the local pedodiversity and spatial heterogeneity of soils rather than larger-scale averages. For example, Liechty et al. (1997) found similar total carbon and nitrogen stocks in soils of old-growth forest stands with and without abundant pit-and-mound topography in upper Michigan. However, spatial heterogeneity is increased by tree uprooting as forest floor organic matter is mixed into the mineral soil of mounds and plant litter accumulates in pits. In humid climates and on poorly drained soils, wet conditions in pits can suppress root growth, litter decomposition, and soil invertebrate activity.

The extent and depth of pit-and-mound microtopography obviously is dependent upon the size of the uprooted trees. The persistence of the resulting microtopography also depends upon tree size, so that old-growth forests would be expected to retain more pedodiversity. Pit-and-mound microtopography can persist for surprisingly long periods, but recent observations indicate that the persistence of pits and mounds depends primarily on soil texture and porosity (Samonil et al. 2010). At the extreme, Samonil et al. (2016) observed that, on sandy outwash soils in upper Michigan with very low innate erodibility, pits and mounds can still be detected over 6,000 years after formation, whereas 500 to 2,000 years is more typical on finer soils. Taking into account the frequency of tree uprooting and the area disturbed, Samonil et al. (2010) concluded that the turnover time of soils in virgin temperate forests is on the order of 1,000 years. In general, pits fill in more quickly than mounds erode (Samonil et al. 2010). Plotkin et al. (2017) observed that 11 percent of the mounds formed from blowdowns in the 1938 hurricane at the Pisgah old-growth forest in New Hampshire were still over one meter high half a century later!

The deep soil mixing from uprooting of large trees eliminates surface horizons and mixes forest floor organic matter into mineral soil. One effect of this pedoturbation may be the interruption of paludification, the accumulation of mineral nutrients in slowly decaying organic matter that can result in forest "retrogression" due to nutrient limitation. Although this process has been observed in wet temperate conifer forests (Bormann et al. 1995), it has not been demonstrated in eastern old-growth forests. Consequently, the importance of pedoturbation for forest health deserves further study. Notably, pedoturbation resets surface soil horizon formation, a process that appears to proceed more rapidly in pits than mounds, at least in Spodosols where spodic horizon formation is particularly rapid (Samonil et al. 2016).

## *Roots and Mycorrhizae*

There is little basis for concluding that systematic differences exist between the root systems of eastern old-growth forests and younger stands. Some reasons for this conclusion are 1) few measurements of old-growth forest roots have been reported owing to the difficulty of measurement; 2) forest tree root systems exhibit high spatial variability making the detection of patterns challenging; and 3) factors other than forest age may override disturbance history, especially climate, soil fertility, depth, stoniness, etc. However, some evidence does exist for trends in forest root systems across younger stand ages, but even here the patterns appear to vary across sites and regions. Considering first the small feeder roots that provide the trees with soil resources, certainly this fine root biomass increases during early stages of stand development; however, the timing of a peak in fine root biomass sometimes coincides with the early peak in stand leaf area (Claus and George 2005), whereas in other cases, it may continue to increase for decades longer (Yanai et al. 2006). Some evidence suggests that the ratio of fine-root biomass to leaf area remains constant across later stages of stand development (Bauhus and Bartsch 1996), but in other cases, an increase in this ratio may coincide with decreased soil nutrient availability as would be expected from a functional standpoint (i.e., more fine roots needed to obtain soil resources). The depth distribution of fine roots also does not appear to differ systematically between old-growth and younger forests (Bauhus and Bartsch 1996), presumably because the depth distribution exhibits idiosyncratic patterns related to forest floor development, soil mixing, profile development, texture, hydrology, parent material, and other factors. Although we might expect that the high pedodiversity in old-growth forests should lead to high spatial variation in fine-root biomass, no studies have demonstrated such a pattern in eastern old-growth forests.

Obviously, the biomass of coarse, woody roots increases with stand age, probably roughly in parallel with aboveground biomass, but again few measurements are available. Based on the extraordinary allometric measurements at Hubbard Brook Experimental Forest by Whittaker et al. (1974), who excavated the root systems of large trees up to 63 centimeters DBH "with the encouragement of dynamite" (p. 235), the ratio of total belowground biomass to aboveground biomass of northern hardwood trees appears to increase slightly for larger trees as would be expected from the standpoint of wind firmness of tall trees.

Mycorrhizal associations are an ubiquitous feature of all forest trees and are critically important for forest productivity. These associations are symbiotic relationships between mycorrhizal fungi and tree roots, helping trees acquire water and nutrients, and sometimes protection from root pathogens, in exchange for photosynthate supplied to the fungi. There is some evidence for differences in mycorrhizal associations between young and more mature forest stands (Twieg et al. 2007), but this has not been reported for eastern old-growth forests. In theory, either changing forest composition (e.g., arbuscular versus ectomycorrhizal associated trees) or shifts in nutrient availability (e.g., nitrogen versus phosphorus, organic nitrogen; Lilleskov and Bruns 2003) and its spatial variation would be expected to cause successional changes in mycorrhizal communities. Moreover, Johnson et al. (2005) concluded that, in boreal forests, plant species richness is related to mycorrhizal species richness. Nevertheless, Dickie et al. (2013) recently concluded that mycorrhizal communities do not exhibit consistent trends with ecosystem development for many of the same reasons listed for fine roots.

A prominent and interesting feature of belowground dynamics is the so-called "wood-wide web" (Helgason et al. 1998) in which trees are linked together through the mycorrhizal fungal network where carbon and nutrients can be transferred between trees—even those of different species (Figure 10-1). Perhaps this web of interaction becomes more complex in old-growth forests coinciding with structural complexity of the ecosystem; however, this subject has received less attention in eastern as compared to western old-growth forests.

One important feature of old-growth forests that certainly influences the distribution of fine roots and mycorrhizae is the abundance of coarse woody debris. Although fine roots often proliferate in decaying wood in eastern forests, the abundance of CWD is not sufficient to support more than a few percent of the forest fine-root system (Arthur et al. 1993). However, from a diversity standpoint, CWD does provide a niche for particular species of ectomycorrhizal fungi that colonize decaying wood (Tedersoo et al. 2003; figure 10-1).

The woody root system of large trees in old-growth forests also could play a significant role in forest hydrology. As mentioned earlier, woody roots act as a conduit for rapid deep percolation of rainwater as indicated by using dye tracers (Schwarzel et al. 2012). Moreover, dead roots form channels in soil that act as pipes for deep routing of water; these root channels can persist in fine, highly structured soils and, thus, would be expected to accumulate with increasing stand age, though no such evidence has been reported.

### *Soil Carbon Cycle*

Forests contain the largest terrestrial carbon stock on Earth, and the majority of that carbon is stored in the soil. Forest harvest often results in a decrease of soil carbon storage, mostly from the surface horizons (Nave et al. 2010); thus, protection of old-growth forests supplies a global ecosystem service in the form of soil carbon retention. Do old-growth forest soils also sequester additional carbon in parallel with the aboveground carbon accumulation described in chapter 14? In theory, soils of old-growth forests should be at or near carbon saturation because nearly all the sites where carbon is stabilized should already be occupied. Nevertheless, some empirical observations suggest that carbon may be accumulating in surface soil (Zhou et al. 2006) or deep soil (Tang et al. 2009) of some old-growth forests. What could explain such unexpected observations?

Soil carbon stocks represent the balance between inputs of carbon from plant detritus and outputs by heterotrophic respiration (decomposition), leaching, and erosion. Increased inputs of detrital carbon to old-growth forest soils might accompany continued aboveground biomass accumulation. However, most of the carbon that is stabilized in soils (i.e., extremely slowly decomposed) is actually derived from microbial residues so that increased inputs to the stabilized carbon pool requires a mechanism that causes greater microbial biomass turnover. Perhaps global change drivers, such as climate change, increasing atmospheric carbon dioxide or nitrogen deposition, have stimulated a higher supply of microbial residues in some old-growth forests. However, the principal mechanisms by which soil carbon is stabilized against microbial degradation are strong interactions with mineral surfaces (clay, silt, amorphous metal oxides) and physical protection within soil microaggregates. These sites of stabilization are thought to be near saturation in most forest soils so that even increased inputs of microbial residues would not be expected to result in soil carbon accumulation (Wiesmeier et al. 2014). One recent suggestion is that carbon may be accumulating (at least temporarily) in some soils in the form of unprotected particulate organic matter (Castellano et al. 2015), and perhaps that could contribute to observations of soil carbon accumulation in old-growth forest soils. In any case, more and better measurements of soil carbon stocks and their temporal changes are needed to determine how widely this phenomenon may be occurring in mature forests worldwide.

## *Nitrogen Cycling*

The nitrogen dynamics of eastern old-growth forests have received considerable study because nitrogen is often the most limiting nutrient in temperate forests, and atmospheric pollution has greatly elevated the inputs of this key element, leading to concerns about ecosystem nitrogen saturation. In theory, retention of nitrogen in forests is expected to peak early in succession, before declining in old age as live biomass reaches a maximum, and old-growth than in mature, second-growth forests (deMaynadier and Hunter 1995; Hicks and Pearson 2003) or where coarse woody debris is silviculturally enhanced to emulate old-growth conditions (McKenny et al. 2006). These salamanders spend most of their time in the soil and forest floor, feeding on microarthropods (mites and springtails) and hiding in cool, moist microhabitats beneath rocks and dead logs. Notably, invasion of northern forests by lumbricid earthworms could decrease habitat quality by eliminating the forest floor and consequently reducing the abundance of soil microarthropods.

Given their low reproductive rate, narrow thermal tolerance, and limited dispersal ability, amphibians may be particularly sensitive to rapid climate change. For this reason, old-growth forests that provide particularly high-quality microhabitat conditions could serve as valuable climate refugia for plethodontid salamanders. A long-term re-survey of salamander populations in the southern Appalachians suggested that increase in abundance at both low and high elevations was associated primarily with forest maturation rather than climate warming; at low-elevation sites salamanders were near the limit of their thermal tolerance but forest recovery from early twentieth century logging apparently compensated for temperature effects (Moskwik 2014).

## Conclusion

The hidden belowground dynamics of eastern old-growth forests are a reflection of the distinctive structural complexity of these ecosystems aboveground. Large trees, gaps, and microtopography lead to greater pedodiversity than for younger forests. However, further research is needed to demonstrate whether and how such pedodiversity influences functional characteristics and biodiversity of eastern old-growth forests.

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Attachment 07

# Old-growth red spruce forests as reservoirs of genetic diversity and reproductive fitness

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# Old-growth red spruce forests as reservoirs of genetic diversity and reproductive fitness

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**Abstract** Old-growth forests are assumed to be potential reservoirs of genetic diversity for the dominant tree species, yet there is little empirical evidence for this assumption. Our aim was to characterize the relationship of stand traits, such as age, height and stem diameter, with the genetic and reproductive status of old-growth and older second-growth stands of red spruce (*Picea rubens* Sarg.) in eastern Canada. We found strong relationships between height growth (a fitness trait) and measures of genetic diversity based on allozyme analyses in red spruce. The negative relationship between height and the proportion of rare alleles suggests that high proportions of these rare alleles may be deleterious to growth performance. Latent genetic potential, however, showed a significant and positive relationship with height. Stand age was not correlated to height, but was correlated to seedling progeny height. In late-successional species such as red spruce, age and size (e.g., height and stem diameter) relationships may be strongly influenced by local stand disturbance dynamics that determine availability of light, growing space, moisture and nutrients. In larger and older stands, age appeared to provide a good surrogate measure or indicator for genetic diversity and progeny height growth. However, in smaller and more isolated populations, these age and fitness relationships may be strongly influenced by the effects of inbreeding and genetic drift. Therefore, older populations or old-growth forests may represent superior seed sources, but only if they are also of sufficient size and structure (e.g., stem density and spatial family structure) to avoid the effects of inbreeding and genetic drift. Thus, larger and older forests appear to have an important evolutionary role as reservoirs of both genetic diversity and reproductive fitness. Given the rapid environmental changes anticipated (as a result of climate change, increasing population isolation through fragmentation, or following the introduction of exotic pests and diseases) these older populations of trees may have a valuable function in maintaining the adaptive potential of tree species.

**Keywords** Conservation · Genetic diversity · Inbreeding · Old-growth forests · Reproductive fitness

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## Introduction

Genetic diversity provides the evolutionary potential for sustaining forest health in the face of environmental change. Therefore, conserving the genetic diversity of native trees, as the dominant life forms of forested ecosystems, has special significance. Old-growth forests are considered to have great value for species conservation (Anonymous 2000) by providing a special habitat for an array of forest-dependent wildlife. These older populations may also serve as reservoirs of genetic diversity and reproductive fitness, important for maintaining populations of native trees under pressure from environmental changes. However, there is very little empirical evidence supporting the assumption that old-growth forests serve as reservoirs of genetic diversity or fitness.

The Acadian Forest Region (AFR) covers most of the Maritime provinces (Nova Scotia, New Brunswick and Prince Edward Island) of Canada (Rowe 1972). Except for a small area of boreal forest, the forest cover is typical of much of the Temperate Zone of northeastern North America, where natural forest succession, in the absence of stand-replacing disturbances such as fire, tends towards the development of late-successional forest types composed of long-lived, relatively shade-tolerant trees, such as eastern hemlock (*Tsuga canadensis*), red spruce

(*Picea rubens*), sugar maple (*Acer saccharum*), American beech (*Fagus grandifolia*) and yellow birch (*Betula alleghaniensis*). One of the most important distinguishing features of the AFR is the high proportion of red spruce (Loucks 1962; Rowe 1972), a species adapted to the high atmospheric moisture that prevails in the AFR. Red spruce is commonly associated with the red spruce-eastern hemlock-eastern white pine (*Pinus strobus*) species complex, which comprises a mostly shade-tolerant coniferous tree species association, with eastern white pine as a legacy from an earlier successional stage. Red spruce also occurs within mixedwood forests, together with shade-tolerant hardwood trees. These climatic climax associations are most commonly found on xeric to mesic lowland sites and, to a lesser extent, in upland areas of Atlantic Canada.

Several hundred years of land clearing for agriculture and timber harvesting has eliminated most of the old-growth forest in the AFR and throughout the northeastern temperate forests of North America (Korstian 1937; Gordon 1994; Davis 1996). In this older forest, the average age of the dominant trees exceeds 150 years and the oldest trees are approaching their maximum longevity of 300–400 years (Cogbill 1996; Mosseler et al. 2000). What little old-growth forest remains is largely restricted to small isolated stands, often found in steep gorges that were inaccessible to harvesting and agriculture, or areas that either were protected or escaped harvesting. Late-successional, old-growth forest types, dominated by shade-tolerant conifers such as red spruce, are becoming increasingly rare. These forest types have great commercial value and, because of their ecophysiological adaptations, present the forest industry with important silvicultural alternatives to clearcutting, and the intensive forest management regimes that normally follow complete forest clearing. The conservation of these declining red spruce-dominated forest types has become an important issue in temperate forests such as the AFR and further west into the Great Lakes – St. Lawrence Forest Region of Ontario. The reproductive and genetic status of the red spruce component of these late-successional forests has been characterized across the Canadian range, from Nova Scotia to the geographically disjunct populations of Ontario in the northwestern portion of the species' range (Mosseler et al. 2000; Rajora et al. 2000).

From a genetic perspective, very little attention has been given to the implications of the loss of late-successional tree species and forest types and, in particular, the oldest stages of forest development. Most forest genetics literature has focused on genetic aspects related to tree improvement and selective breeding activities.

High levels of genetic diversity are generally accepted as essential for facilitating the adaptive responses required to adjust to anticipated climate and other environmental changes. The objective of this study was to examine relationships between stand traits, such as tree age, stem height and stem diameter, in ten natural populations of red spruce with: (1) genetic diversity parameters, (2) reproductive fitness traits, and (3) progeny growth. These relationships help us to understand what these older populations represent in terms of genetic resources and as potential reservoirs of genetic diversity and reproductive fitness.

## Materials and methods

### Red spruce populations and sampling

Ten red spruce populations, five from New Brunswick and Nova Scotia, and five from Ontario (Table 1), were studied as described in Mosseler et al. (2000) and Rajora et al. (2000). The sampled populations were all located within a similar range of latitude and elevation. Maritime populations consisted of large, extensive stands that normally contained several thousand mature trees contributing to the reproductive gene pool. Ontario red spruce populations, however, generally consisted of much smaller stands occurring as remnant patches, often with fewer than 50 mature trees that were sometimes isolated from adjacent stands by distances that would be expected to restrict pollination or seed dispersal among stands. As most of the Ontario stands had only 15 to 20 red spruce trees bearing a cone crop, we limited our sampling to about 15 trees per population in order to keep relatively uniform sample sizes. This sample size represented an almost complete (80–90%) female reproductive census and 35–65% of the total red spruce individuals from the Ontario populations. The Nova Scotia red spruce populations at Abraham Lake and Rossignol Lake represent relatively undisturbed, old-growth forest stands dominated by red spruce of all ages, including trees presumed to be well over 300 years of age, as determined from wood increment corings. Data on height, diameter and age of individual sampled trees were recorded (Mosseler et al. 2000).

### Seed processing, germination and seedling growth

Cones were collected from individual sampled trees and the seeds were processed as described in Mosseler et al. (2000). Various cone and seed traits, including the total number of seeds, the number and proportion of empty and filled seeds per cone, and the proportion of filled to developed seeds, were measured and calculated, as were population means for these traits. Seed was germinated from individual open-pollinated families under glasshouse conditions and seedling height was measured to the nearest 5 mm 169 days after sowing.

### Genetic diversity analysis

Genetic diversity parameters of the populations were determined by assaying 37 allozyme loci, coding for 15 enzymes in haploid megagametophytes as described in Rajora et al. (2000). Of the 37 loci studied, eight were invariant (monomorphic) in all ten red spruce populations and 29 were polymorphic. The traits examined include: (1) the percentage of monomorphic loci, (2) the percentage of polymorphic loci, (3) the mean number of alleles per locus, (4) the latent genetic potential, (5) the proportion of rare alleles, and (6) the mean observed heterozygosity.

### Statistical analyses

The regional (Ontario versus Maritime) effect was tested in a covariance analysis to examine tree height growth in relation to various genetic diversity traits in a way analogous to the analysis of covariance of female effects presented by Major and Johnsen (1996), using the model $Y_{ij} = B_0 + B_{0i} + B_1X_{ij} + B_{1i}X_{ij} + e_{ij}$, where $Y_{ij}$ is tree height of the $j^{th}$ population of the $i^{th}$ region, $B_0$ and $B_1$ are average regression coefficients, $B_{0i}$ and $B_{1i}$ are region coeffi-

**Table 1** Geographic coordinates, elevation, and population abbreviations for sampled red spruce populations

| Location of populations (population abbreviation) | Latitude | Longitude | Elevation (m) |
|---|---|---|---|
| *Maritimes:* | | | |
| 1. Rossignol Lake, NS (RL) | 45°08′ | 65°14′ | 100 |
| 2. Abraham Lake, NS (AL) | 45°10′ | 62°38′ | 185 |
| 3. Quiddy River, NB (QR) | 45°31′ | 65°12′ | 100 |
| 4. Hurlett Road, NB (HR) | 46°07′ | 66°39′ | 185 |
| 5. Blowdown Brook, NB (BB) | 46°41′ | 67°36′ | 380 |
| *Ontario:* | | | |
| 6. Gloucester Township (GT) | 45°21′ | 75°32′ | 80 |
| 7. Haliburton Forest (HF) | 45°13′ | 78°35′ | 185 |
| 8. Bruton Clyde Reserve (BCR) | 45°17′ | 78°17′ | 460 |
| 9. Centennial Ridges (CR) | 45°34′ | 78°25′ | 510 |
| 10. Blythe Township (BT) | 46°32′ | 79°32′ | 380 |

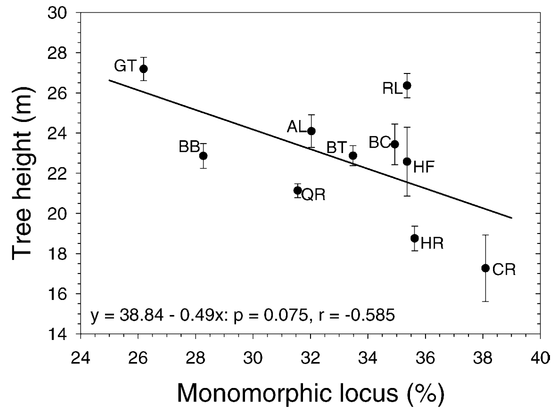


**Fig. 1** Relationship between tree height (mean and SE) and percentage of monomorphic loci by population (see Table 1 for population abbreviations)

cients, $X_{ij}$ is the independent variable (e.g., genetic diversity traits such as the percentage of poly- and mono-morphic loci, the mean number of alleles per locus, the latent genetic potential, the proportion of rare alleles, and heterozygosity), and $e_{ji}$ is the error term. In this analysis, three sources of variation are identified: (1) genetic diversity trait (covariate), (2) region, and (3) region × covariate. Significant region effects indicate differences in region means (i.e., differences in $B_{0i}$ coefficients, if $B_{1i}$ coefficients are similar) and significant region × covariate effects indicate differences in the slopes ($B_{1i}$ coefficients) between regions.

The relationships (*r*-value) and significance (*p*-value) of stand age, tree height, tree diameter and height of the open-pollinated progeny with genetic diversity parameters were determined by correlation analysis based on the population means for these traits. Two-dimensional plots with *p*- and *r*-values were constructed to portray these relationships for the stands identified in Table 1.

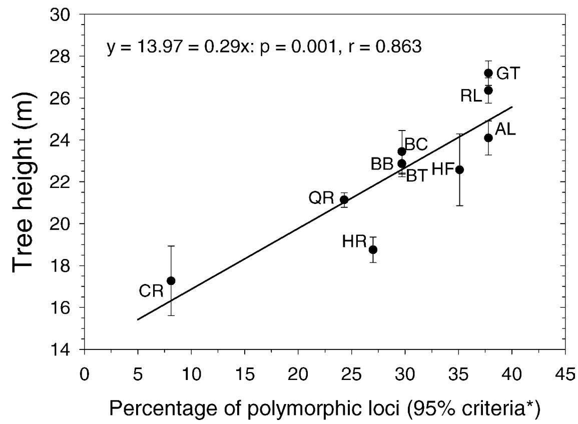


**Fig. 2** Relationship between tree height (mean and SE) and percentage of polymorphic loci (genetic diversity) at the 95% criterion by population (see Table 1 for population abbreviations). *A locus was considered polymorphic if the frequency of the most common allele did not exceed 0.95

## Results

Correlations between stand averages for traits such as tree height, diameter and age resulted in no significant relationships among these traits (data not shown). For instance, average stand height showed no relationship to average stand age ($p = 0.685$). However, average stand height was significantly correlated with a number of genetic diversity traits. The region effect (e.g., Ontario vs Maritimes) was not significant for any of the genetic diversity traits examined. Mean stand height was negatively correlated to percent monomorphic loci ($r = -0.585$) (Fig. 1). The Gloucester Township (Ontario) population was monomorphic for eight of the allozyme loci that were normally polymorphic in most of the other populations. The Centennial Ridges (Ontario) population was monomorphic for 19 loci that were normally polymorphic in most of the other populations. Rossignol Lake (Nova Scotia) appears to be an outlier in this relationship between percent monomorphism and average stand height growth.

Average stand height was strongly ($p = 0.001$) and positively ($r = 0.863$) correlated with the percent polymorphic loci (Fig. 2), when a locus was considered polymorphic if the frequency of the most common allele did not exceed 0.95 (95% criterion). There was also a significant positive correlation ($p = 0.02$, $r = 0.725$) between mean stand height and percent polymorphic loci, when a locus was considered polymorphic if the frequency of the most common allele did not exceed 0.99 (99% criterion) (data not shown). The populations at Gloucester Township, Rossignol Lake and Abraham Lake (Nova Scotia) were among the most polymorphic. The ranking of the ten different populations was relatively consistent regardless of whether the percentage of polymorphic loci was calculated based on the 95% or 99% criteria.

Average stand height was also strongly and positively correlated to the mean number of alleles per locus (Fig. 3A) ($r = 0.750$, $p = 0.012$) and latent genetic potential (Fig. 3B) ($r = 0.718$, $p = 0.019$). However, the relationship between the average tree height within a stand

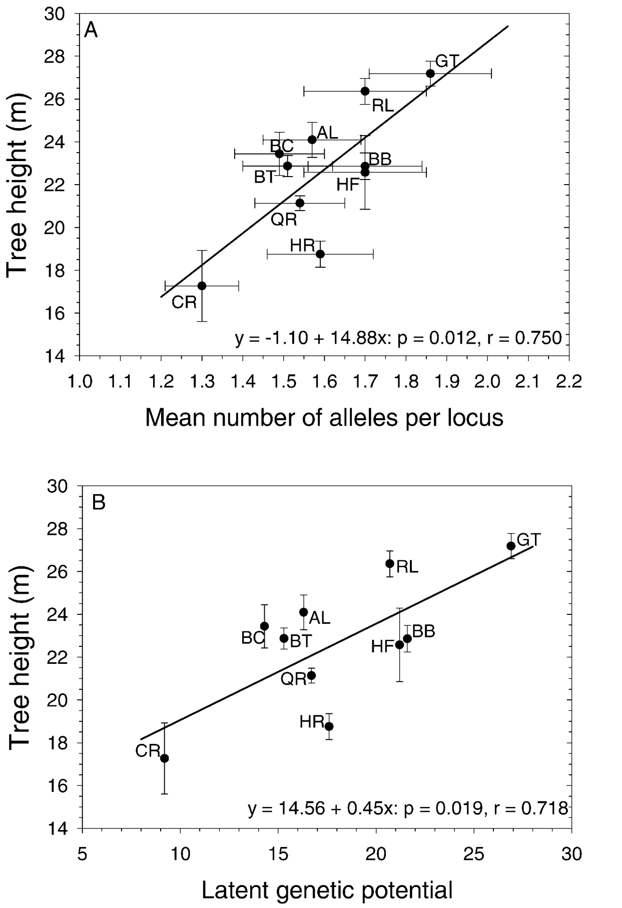


**Fig. 3** Relationship between tree height (mean and SE) and (**A**) mean number of alleles per locus, and (**B**) latent genetic potential by population (see Table 1 for population abbreviations)

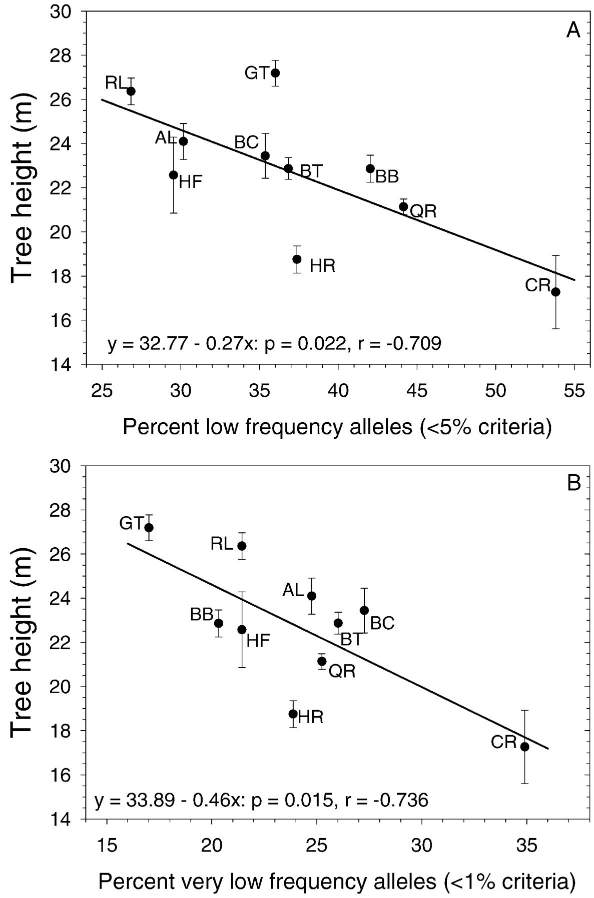


**Fig. 4** Relationship between tree height (mean and SE) and rare alleles at (**A**) 5% criterion, and (**B**) 1% criterion, by population (see Table 1 for population abbreviations)

and the percentage of rare alleles (Fig. 4A and B) showed a strong decline in height growth with increasing proportions of rare alleles. The ranking of individual populations was somewhat different when comparing the 1% and 5% criteria as the frequency threshold for rare alleles (Fig. 4A and B).

A strong positive relationship was detected between stand tree height and mean observed heterozygosity (Fig. 5) ($r$ = 0.698, $p$ = 0.025). Populations from Gloucester Township, Rossignol Lake and Abraham Lake once again showed some of the highest genetic diversity in terms of observed heterozygosity.

There was a strong negative relationship between the proportion of empty seeds, which is a measure of reproductive fitness, and average stand age ($r$ = –0.731, $p = 0.016$) (Fig. 6A). Covariate analysis indicated no significant regional effect ($p = 0.764$) or region × age interaction ($p = 0.362$). There was a strong positive correlation between average seedling progeny height, which is a measure of genetic fitness, and the average stand age of their parents ($r = 0.568$) (Fig. 6B). Covariate analysis indicated no significant regional effect ($p$ = 0.528) or region × age interaction ($p = 0.255$).

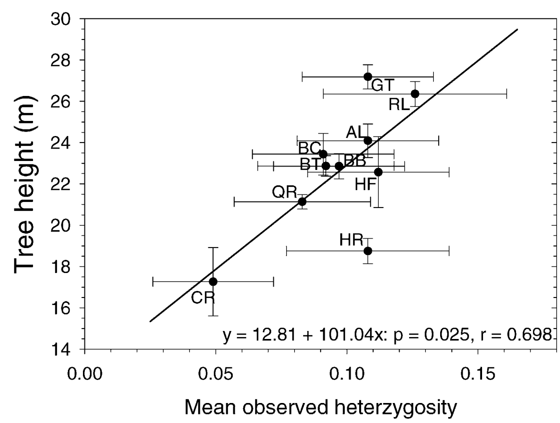


**Fig. 5** Relationship between tree height (mean and SE) and mean observed heterozygosity by population (see Table 1 for population abbreviations)

Correlations between average parental population diversity traits and average seedling progeny height resulted in no significant relationships ($p$ > 0.300, data not shown).

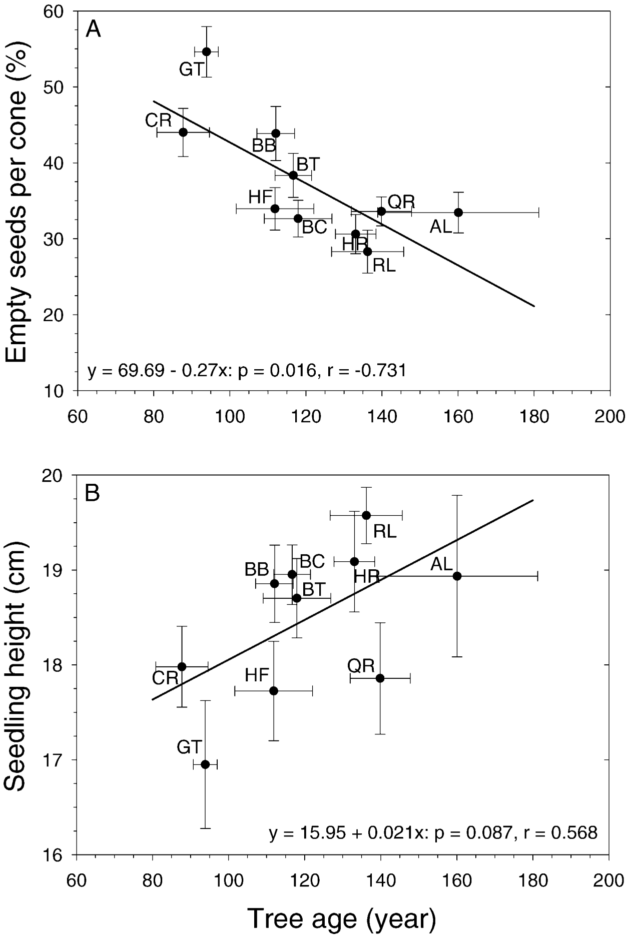


**Fig. 6** Relationship between (**A**) empty seeds production per cone, and (**B**) seedling progeny height growth, to stand age by population (see Table 1 for population abbreviations)

## Discussion

Old-growth forest is a stage of forest development that represents a unique physical environment in terms of light availability, atmospheric moisture, nutrient regime, biomass structure and temporal stability of biomass structure. The declining representation of the old-growth stage of forest development has become a conservation issue because of the perceived ecological value and role of old-growth forests in biodiversity conservation (Cogbill 1996; Meier et al. 1996; Selva 1996). However, the role of these forests as important gene pools and seed sources has received much less attention. Our study indicates that old-growth red spruce populations may also serve as important reservoirs of genetic diversity and reproductive fitness.

The negative relationship between average stand height and percent monomorphic loci (Fig. 1), the strong positive correlations between average stand height and the percentage of polymorphic loci (Fig. 2), measures of allelic richness (Fig. 3A and B) and observed heterozygosity (Fig. 5), support the relationship between growth and genetic diversity in red spruce. In pitch pine (*Pinus rigida*), the positive relationship between tree diameter and heterozygosity also increased with stand age (Ledig et al. 1983). Increased genetic diversity (e.g., individual heterozygosity) may confer some inherent superiority in individual fitness and the capacity to buffer against environmental changes (Lerner 1954; Ledig et al. 1983; Mitton and Grant 1984; Allendorf and Leary 1986). Allozyme heterozygosity was found to be associated with stem diameter in trembling aspen, *Populus tremuloides* (Mitton et al. 1981), whereas no such relationship was observed in Ponderosa pine, *Pinus ponderosa*, and Lodgepole pine, *Pinus contorta* (Mitton et al. 1981). Most allozyme variation is thought to be largely neutral with respect to fitness (Kimura 1979). However, its selective value has not been adequately determined in forest trees. Nevertheless, we assumed that allozyme variation corresponded with variation at adaptively significant genes, and that its relationship with growth and other measures of fitness may be particularly important in a species with such low genetic diversity as red spruce (Morgenstern et al. 1981; Fowler et al. 1988; Eckert 1989; Bobola et al. 1992; Hawley and DeHayes 1994; Perron et al. 1995; Rajora et al. 2000) in comparison with most other trees for which allozyme-based estimates of genetic diversity are available (Hamrick and Godt 1990). The relatively low genetic diversity found in red spruce has been implicated in its decline (DeHayes and Hawley 1988, 1992).

The negative relationship between height growth and the proportion of rare alleles (Fig. 4A and B) suggests that high proportions of these rare alleles may be deleterious to height growth, as was observed in pitch pine (Bush and Smouse 1992). Although showing a negative effect, under an adaptive gene action hypothesis, the rare alleles in a population may also represent much of the genetic potential required for population adaptation to environmental changes. Latent genetic potential (LGP), which is the difference between the total number of alleles and the effective number of alleles summed over all loci (Bergmann et al. 1990), is a measure of allelic richness that emphasizes richness in terms of low frequency or rare alleles.

In most short-lived, early successional tree species, growing in open (fully exposed) environments, tree diameter growth is normally correlated with height growth. Intuitively, height and diameter growth could be considered as potential surrogate measures for age, but we detected no correlation between height and age. There are several reasons why this relationship between height and age might not hold in long-lived, late-successional trees such as red spruce. In long-lived, shade-tolerant trees, adapted to natural regeneration and growth under an established forest canopy, diameter growth fluctuates dramatically in relation to light levels created by the presence or absence of their nearest neighbors within a stand. In the case of red spruce, this phenomenon was quite evident when aging individual trees was based on stem increment cores (Mosseler et al.

2000). Growth (stem diameter) profiles varied dramatically over the lifespan of an individual, with alternating random episodes of suppression and release based on the effects of highly localized canopy gap disturbance events, such as the death of neighboring trees or small groups of trees.

Although the Gloucester Township population from Ontario was one of the tallest and most genetically diverse of the sampled populations, it was also the smallest and most isolated population with only 36 reproductively mature individuals. There was strong evidence from a previous study that this stand had experienced genetic drift based on the unusually high frequency of chlorophyll-deficient seedlings (Mosseler et al. 2000). This population produced seedling progeny with the lowest vigor in terms of height growth (Fig. 6B), suggesting increased inbreeding and inbreeding depression due to the effects of small population size and isolation. These differences between the genetic status of the parental population and its seedling progeny indicate that the decline of red spruce in Ontario may be a relatively recent phenomenon, having occurred within the past several generations following a period of intensive logging activity in Ontario coinciding with European settlement. Thus, the extant Gloucester Township population may represent a small remnant of a much larger population that existed before the extensive logging that accompanied European settlement.

The mixed mating and breeding system of conifers (Sorensen 1982) and the existence of close family structure in natural populations, may increase levels of self-fertilization and consanguineous mating, respectively (Rajora et al. 2000). Inbreeding affects all traits by increasing homozygosity within individuals and populations. In natural populations of red spruce, both reproductive and vegetative fitness traits are affected simultaneously by inbreeding and inbreeding depression (Mosseler et al. 2000). The largest and oldest stands of old-growth red spruce, located at Rossignol Lake and Abraham Lake in Nova Scotia, had among the highest genetic diversity, and also had among the tallest and oldest trees. These populations also produced the fastest growing (tallest) seedling progeny. Thus, age in these large, old-growth stands may be a good surrogate measure for genetic diversity and progeny growth performance; whereas in the smaller, isolated populations of Ontario (such as Gloucester Township) and elsewhere in the Maritimes, these age and fitness relationships may be obscured by the effects of inbreeding (e.g., Gloucester Township). We hypothesize that the better performing progeny have greater genetic diversity (e.g., heterozygosity and allelic richness). This has been demonstrated in eastern white pine, where fixation rates in the filial seed population increased in smaller, isolated and more widely spaced (lower density) populations (Rajora et al. 2002). The high proportion of empty seeds in the Gloucester Township population demonstrates the effects of inbreeding on reproductive fitness (e.g., filled seed production) and in the poor growth performance of the resulting seedling population, whereas the extant parental population appears to have maintained its genetic integrity. Therefore, old-growth forests can represent superior seed sources, but only if they are also of a sufficient size and density to avoid the effects of inbreeding and genetic drift.

The loss of genetic diversity can play a decisive role in species persistence over the longer term because such diversity allows species to remain fit and adapt to changing environments (Lande 1996). The Fundamental Theorem of Natural Selection (Fisher 1930) states that the rate of increase in fitness of any organism at any time is equal to its genetic variance in fitness. Thus, the conservation and maintenance of genetic diversity in natural populations is critical to their adaptation and survival, particularly in rapidly changing environments. Earlier studies have shown that both old growth and older second-growth red spruce populations had lower genetic diversity than other conifers with similar life history traits (Hamrick and Godt 1990; Rajora et al. 2000).

Our results on the reproductive and genetic status of red spruce demonstrate significant positive relationships between average population age and genetic fitness in traits related to reproductive success (Fig. 6A) and seedling progeny height growth (Fig. 6B). Older trees produced not only better quality seed in terms of height growth in the resulting progeny but also produced less empty seed. Therefore, a direct relationship may exist between the age of the parent tree and its reproductive and genetic fitness. These results suggest that older populations of red spruce may have special genetic characteristics or processes that maintain or promote the genetic potential of their progeny in terms of growth performance, and also the reproductive capacity of natural populations. As populations age, one might expect the average level of genetic diversity to increase as natural selection against inbred individuals, due to the effects of inbreeding depression, reduces the number of inbred trees (Rajora et al. 2002). We know from earlier work (Mosseler et al. 2000; Rajora et al. 2000) that high levels of inbreeding occur in red spruce and that such high levels of inbreeding are tolerated in the viable seed produced by red spruce trees.

Older forests may have an important role as reservoirs of genetic diversity and reproductive capacity, by ensuring that populations maintain the genetic potential for adaptation to rapidly changing climate conditions and landscape patterns due to human impacts, and following the introduction of diseases and pests. However, the potential genetic advantages of older populations, as reservoirs of genetic diversity, can be undermined by inbreeding and genetic drift in small, isolated populations. The relationships observed among reproductive, genetic, and progeny fitness traits in red spruce are important because reproductive success and growth performance are the main components of fitness driving species survival and evolution. These relationships within old-growth red spruce stands present some of the strongest biological arguments in support of old-growth forest protection. A concerted effort should be made to maintain an adequate proportion of these older populations as reservoirs of genetic diversity and reproductive fitness to ensure the dispersal of genetically diverse seed across a landscape of changing environments.

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Attachment 08

# Effects of Harvesting on Genetic Diversity in Old-Growth Eastern White Pine in Ontario, Canada

# Effects of Harvesting on Genetic Diversity in Old-Growth Eastern White Pine in Ontario, Canada

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**Abstract:** *Genetic diversity measures at 54 isozyme loci coding for 16 enzymes in megagametophytes were compared between preharvest and postharvest gene pools of two adjacent virgin, old-growth (~250 years) stands of eastern white pine (*Pinus strobus* L.) in the Galloway Lake Old Pine Area of central Ontario. The concurrence of genetic diversity changes between the stands suggests that real and repeatable genetic erosion occurred in these gene pools as a result of harvesting. The total and mean number of alleles detected in each stand were reduced by approximately 25% after tree density reductions of 75%. The percentage of polymorphic loci dropped by about 33% from preharvest levels. About 40% of the low frequency ($0.25 > p \geq 0.01$) alleles and 80% of the rare ($p < 0.01$) alleles were lost from each stand because of harvesting. Hypothetical multilocus gametic diversity was reduced by about 40% in each stand after harvesting. Latent genetic potential of each stand was reduced by about 50%, suggesting that the ability of these gene pools to adapt to changing environmental conditions may have been compromised. Heterozygosity estimates in the postharvest stands did not reflect reductions in allelic richness due to harvesting. Observed heterozygosity increased by 12% in one stand after harvesting, even though other genetic diversity measures decreased. Gene frequency changes due to harvesting imply that gene pools of naturally regenerated progeny stands may be quite different from the original parental stands. Silvicultural practices should ensure that the gene pools of remaining pristine old-growth stands have been reconstituted in the regenerating stands.*

Efecto de la Cosecha Sobre la Diversidad Genética de un Bosque Maduro de Pino Blanco del Este

**Resumen:** *Las medidas de diversidad genética de 54 loci de isozimas que codifican 16 enzimas en megagametofitos fueron comparadas entre pozas génicas pre- y post-cosecha de dos bosques maduros de pino blanco del este (*Pinus strobus* L.) adyacentes en el área Galloway Lake Old Pine del centro de Ontario. La concurrencia de cambios de diversidad genética entre bosques sugiere que la erosión genética real y repetible ocurrió en estas pozas génicas como resultado de la cosecha. El total y la media de alelos detectados en cada bosque se redujeron en 25% aproximadamente después de reducciones de 75% en la densidad de árboles. El porcentaje de loci polimórficos decreció alrededor de 33% respecto a niveles pre-cosecha. Debido a la cosecha, en cada bosque se perdió alrededor del 40% de alelos de baja frecuencia ($0.25 > p \geq 0.01$) y 80% de los alelos raros ($p < 0.01$). La hipotética diversidad gamética multilocus se redujo en 40% en cada bosque después de la cosecha. El potencial genético latente de cada bosque se redujo en 50%, lo que sugiere que se puede haber comprometido la habilidad de estas pozas génicas para adaptarse a condiciones ambientales cambiantes. Las estimaciones de heterocigosis en los bosque post-cosecha no reflejaron reducciones en la riqueza alélica debido a la cosecha. La heterocigosis observada incrementó en 12% en un bosque después de la cosecha, aunque otras medidas de diversidad genética decrecieron. Los cambios en frecuencia génica debido a la co-*

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*secha implican que las pozas génicas de bosques progenitores regenerados naturalmente pueden ser muy diferentes a las de los bosques parentales originales. Las prácticas silviculturales deben asegurar que las pozas génicas de los bosques maduros prístinos se reconstituyan en los bosques regenerados.*

## Introduction

Eastern white pine (*Pinus strobus* L.), once the predominant tree species in forest landscapes of the Great Lakes region of North America, has undergone fundamental population changes over 150 years of heavy exploitation. High-grading and extensive stand harvesting for timber, agricultural, and residential use has resulted in forest fragmentation and reduction of population sizes, and white pine is now a minor forest component over much of its botanical range. This population reduction may have resulted in changes to local gene pools through various genetic mechanisms, including nonrandom selection, reduction in genetic richness of residual breeding populations, inbreeding, and genetic drift (Barnes 1989; Ledig 1992).

There are still areas of undisturbed old-growth white pine forest in Ontario (Perera & Baldwin 1993) that are currently being considered for silvicultural manipulation and eventual harvest. Virgin old-growth stands in Ontario and Quebec constitute most of the remaining undisturbed gene pools of the species and contain genetic diversity accumulated over many generations of mutation, sexual recombination, and natural selection. As white pine is the keystone species in old-growth white pine ecosystems, its continued presence is essential for many floral and faunal associations that delimit these ecosystems (Barnes 1989; Carleton & Gordon 1992; Welch et al. 1992).

Maintenance of genetic diversity in forest tree populations that are undergoing fundamental population changes, whether natural or human-induced, is seen to be the key to adaptability and continued evolution (Gregorius et al. 1985; Müller-Starck 1985; Ledig 1988; Namkoong 1991; Müller-Starck et al. 1992). There is mounting evidence that tree populations that have sustained genetic losses are more susceptible to productivity decline and loss of environmental fitness in the event of major environmental changes (Müller-Starck 1985; Bergmann & Scholz 1987; Bergmann et al. 1990; Oleksyn et al. 1994; Raddi et al. 1994). It is not yet clear, however, how harvesting practices, which remove many or most individuals from intact gene pools, affect genetic diversity and genetic processes because no reported studies have attempted to assess and compare total genetic diversity of intact forest tree gene pools with residual genetic diversity of remnant gene pools after human disturbance (Buchert 1994).

In addition to investigations of geographic variation in morphometric traits through common garden experiments (e.g., Genys 1987), electrophoretic surveys have begun to explore genetic variability in eastern white pine at clone (Eckert et al. 1981; Chagala 1991), stand (Brym & Eckert 1987), regional (Beaulieu & Simon 1994), and rangewide (Ryu & Eckert 1983) levels of genetic organization. Nevertheless, there is no information on population genetic variation of white pine from its Ontario range. Also, no information is available on genetic diversity levels of intact preharvest and residual postharvest gene pools from the same stands. Our study provides the first opportunity to address this aspect.

Intact, undisturbed old-growth white pine stands provide a unique opportunity to develop benchmark information on the level and distribution of genetic diversity that occurs in natural biological systems. These benchmarks and measures are important for development of biologically sustainable silvicultural practices (Ledig 1992; Buchert 1996). In a finite population genetic diversity is expected to be reduced as population size decreases. An understanding of the impact of harvesting on local gene pools will facilitate the monitoring of such practices to ensure their effectiveness in maintaining long-term ecosystem productivity and health. As harvesting proceeds there is also a unique opportunity to measure the effects of silvicultural practices on residual and regenerating stand genetic diversity. If current silvicultural practices substantially reduce genetic diversity in pristine systems, it will be necessary to develop alternative practices that ensure diversity of parental gene pools is maintained in the regenerated stand. We examine effects of harvesting and quantify the reduction in genetic diversity due to harvesting, at 54 allozyme gene loci, by comparing intact preharvest and residual postharvest gene pools in two adjacent old-growth white pine stands.

## Methods

### White Pine Stands and Trees

Two virgin, old-growth white pine stands (A and B) were identified within an area scheduled for harvesting in fall, 1992. The area, located about 100 km north of Sault Ste. Marie, Ontario, in the northwest corner of Wlasy Township, is part of the Galloway Lake Old Pine

**Table 1. Physical data for old-growth white pine trees in stands A and B in the northwest Walasy Township, Ontario.**

| | *Stand A* | | *Stand B* | |
|---|---|---|---|---|
| *Stand parameter* | *Preharvest* | *Postharvest* | *Preharvest* | *Postharvest* |
| Plot area (ha) | 0.67 | | 0.69 | |
| Mean height (m) | 26 | 29 | 27 | 26 |
| Mean DBH (cm) | 53 | 65 | 57 | 62 |
| Basal area ($m^2$) | 24 | 8 | 27 | 8 |
| Mean crown height (m) | 12 | 16 | 14 | 15 |
| Mean crown area ($m^2$) | 601 | 958 | 836 | 883 |
| Mean crown ratio | 0.46 | 0.55 | 0.54 | 0.56 |
| Mean distance to nearest neighbor (m) | 3.5 | 13.5 | 4.5 | 15.0 |
| Total number of white pine trees | 132 | 25 | 106 | 23 |

Area (approximately 47°13′N latitude, 83°56′W longitude). Topography of the area is complex, with rocky knobs of moderate relief interspersed among small lakes, swamps, and drainages. Soil textures vary from very fine sands to silt loams, and soil depths are highly variable, from very shallow on top of rock knobs to shallow or moderately deep on lower slopes and flat terrain (Ecological Services for Planning 1991). The old-growth white pine component in this forest type is assumed to be of fire origin and occurs as scattered individuals (<30 stems/ha) among mixed hardwoods and grades to small "substands" (generally <1 ha), where it is the dominant species (200+ stems/ha).

The selected stands consisted of supercanopy white pine with an average age of 250 years (T. Lynham, pers. comm.), with mixed conifer and hardwood understory. Average physical dimensions of the white pine component in each study stand are given in Table 1. Understory tree species include sugar maple (*Acer saccharum* Marsh.), red maple (*A. rubrum* L.), yellow birch (*Betula alleghaniensis* Britton), white birch (*B. papyrifera* Marsh.), black spruce (*Picea mariana* Mill. B.S.P.), balsam fir (*Abies balsamea* L. Mill.), and northern white cedar (*Thuja occidentalis* L.). The absence of seedling or advanced white pine regeneration in the study stands reflects the apparent need for periodic fire to maintain pine as a fire climax species in this forest type by preparing suitable seedbeds and removing competing herbaceous, shrub, and tree species (Maissurow 1935; Carleton & Gordon 1992).

### Silvicultural Treatments and Material Collection

The study stands are part of a 250-ha area designated for timber harvesting in 1992. A partial cutting system was prescribed with the objectives of extracting timber, encouraging natural regeneration, and maintaining old-growth structural characteristics in residual stands. To achieve this the silvicultural marking prescription called for residual spacing to be 15 m between residual trees in stand A and 20 m between trees in stand B. One half of the residual trees were chosen for seed production potential to ensure natural regeneration. Every other tree marked as a residual was to be chosen for one or more old-growth attributes (e.g., large size, nesting cavities, dead or dying top). In this manner, trees with obvious old-growth characteristics were evenly distributed throughout each stand as were seed production trees. Harvesting was to be done in one cutting cycle, and residual trees were to remain uncut. Additionally, any other merchantable tree species were to be cut during harvest. Site preparation for natural regeneration was to be done by rubber-tired skidder during harvesting, with additional scarification by bulldozer if required.

After each stand was marked for harvest, all white pine trees (132 in stand A and 106 in stand B) were numbered and mapped. Cone and foliage samples were collected from all cone-bearing trees in each stand (95 trees in stand A and 96 trees in stand B) in September 1992. Trees that were not reproducing in 1992 had declining health and vigor and were judged incapable of contributing to the genetic pools of the regenerating stands. Therefore, for the purpose of determining gene pool diversities, we considered inclusion of all cone-bearing trees to be a total census of the individuals within each stand. Seeds from these trees were used for preharvest gene pool analyses. After harvest in October 1992, 25 of the original 95 trees were retained in stand A, whereas 23 of the 96 trees were retained in stand B. These residual trees were identified and used for posharvest gene pool analyses.

Seeds were manually extracted from cones, mounted on paper cards, and x-rayed. We used x-ray images to separate filled seeds from partially filled and empty seeds and stored the seeds at −20°C until analysis.

### Isozyme Analysis of Genetic Diversity

Genotypes and genetic variability of the 191 trees were determined for 54 gene loci in megagametophyte tissue. A total of 27 enzyme systems were screened on a subset of samples with three buffer systems. Sixteen enzyme systems provided consistent and clear resolution of isozymes and were assayed by horizontal starch gel elec-

**Table 2. Enzymes assayed in old-growth white pine stands.**

| *Enzyme* | *EC number* | *Abbreviation* | *Buffer system* | *Number of loci scored* |
|---|---|---|---|---|
| Aspartate aminotransferase | 2.6.1.1 | AAT | 1[a] | 4 |
| Alcohol dehydrogenase | 1.1.1.1 | ADH | 2[b] | 4 |
| Acid phosphatase | 3.1.3.2 | APH | 1 | 2 |
| Adenylate kinase | 2.7.4.3 | AK | 2 | 1 |
| Aldolase | 4.1.2.13 | ALD | 2 | 4 |
| Diaphorase | 1.6.4.3 | DIA | 2 | 5 |
| Glutamate dehydrogenase | 1.4.1.2 | GDH | 2 | 5 |
| Isocitrate dehydrogenase | 1.1.1.42 | IDH | 2 | 4 |
| Leucine aminopeptidase | 3.4.11.1 | LAP | 1 | 2 |
| Malate dehydrogenase | 1.1.1.37 | MDH | 2 | 6 |
| Malic enzyme | 1.1.1.40 | ME | 2 | 1 |
| Menadione reductase | 1.6.99.2 | MNR | 2 | 3 |
| Phosphoglucoisomerase | 5.1.3.9 | PGI | 1 | 3 |
| Phosphoglucomutase | 2.7.5.1 | PGM | 2 | 4 |
| 6-phosphogluconic dehydrogenase | 1.1.1.44 | 6PGD | 2 | 4 |
| Shikimate dehydrogenase | 1.1.1.25 | SKDH | 2 | 2 |

[a]*Electrode buffer, 0.06 M lithium hydroxide and 0.3 M boric acid, pH 8.1; gel buffer, 1:10 dilution of the electrode buffer (Ridgeway et al. 1970).*
[b]*Electrode buffer, 0.125 M TRIS, pH 7.0 with 1.0 M citric acid; gel buffer, 0.05 M L-histidine and 1.4 mM EDTA, pH 7.0 with 1.0 M TRIS. Gels made by using a 1:5 dilution of the gel buffer (modified from Namkoong et al. 1979).*

trophoresis using two buffer systems (Table 2). The remaining 11 enzyme systems were inconsistent and were excluded. Enzyme activity zones were detected in 8 to 10 individual megagametophytes per tree.

Genotypes of individual trees and genetic interpretation of loci and alleles were inferred from the banding patterns in individual megagametophytes. A locus was considered polymorphic if more than one allele was observed. At polymorphic loci both alleles showed equal or almost equal segregation. Numerical designation of isozyme loci and alleles was as follows: for enzymes coded by multiple loci and alleles, the fastest anodally migrating zone was designated locus *1* and the most anodal allozyme at that locus was designated allele *1*. The numbering of alleles and additional loci within an enzyme system progressed sequentially in the cathodal direction, and null alleles were identified as *0*. A red dye marker indicated the migration front on gels and allozyme Rf values were calculated relative to the mobility of the dye marker. Detailed descriptions of electrophoretic banding patterns will be presented elsewhere. The loci resolved are summarized below.

The APH (two loci), AK (one locus), ALD (four loci), and SKDH (two loci) enzyme patterns were consistent with previously reported results in *P. strobus* (Chagala 1991; Eckert et al. 1981).

Neither GDH nor MNR have been previously reported in *P. strobus*. We observed five polymorphic GDH loci and three polymorphic MNR loci in the 191 trees. The *Mnr1* and *Mnr2* exhibited identical banding patterns but different Rf values. Furthermore, *Mnr1-2* had the same electrophoretic mobility as *Mnr2-1*; this two-locus interpretation of MNR was confirmed when 1 tree (tree B12) of 191 trees showed differences in banding patterns between *Mnr1* and *Mnr2*. In a 100-megagametophyte array of seeds from this tree, alleles at these loci segregated 1:1. The *Mnr1* and *Mnr2* were discernable from *Dia1* and *Dia2* by Rf differences and by differences in banding patterns between the 2 enzymes in 11 of the surveyed trees. Nevertheless, the banding patterns of both sets of enzyme loci were identical in the remaining 180 trees, suggesting that these loci are closely linked. The ME enzyme has not been previously reported in *P. strobus*. We observed one locus, which we believe is tightly linked to *Mdh2*. The *Me* banding patterns were identical to *Mdh2*, but Rf values were different and stain intensity was very weak compared to *Mdh2*.

For AAT three loci have been previously reported in *P. strobus* (Beaulieu & Simon 1994; Chagala 1991; Eckert et al. 1981; Ryu 1982). We observed an additional cathodally-migrating locus, *Aat4*, which appeared to be closely linked to *Aat3*. We found band pattern differences between *Aat3* and *Aat4* in 3 out of 191 trees; repeated analysis confirmed two distinct loci. The ADH enzyme was reported as monomorphic by Eckert et al. (1981), whereas we consistently observed four zones of activity, with loci *Adh1* through *Adh3* polymorphic and *Adh4* monomorphic. For DIA Chagala (1991) reported four loci, whereas we detected five. We determined that the slower-migrating allele of *Dia1* overlapped monomorphic *Dia2*, a relationship which is clearly discernable when *Dia1-2* is homozygous, and the three-gene-dose band at the *Dia1-2/Dia2* overlap stains much darker than in alternate genotypes. For IDH Eckert et al. (1981) and Beaulieu and Simon (1994) reported a single monomorphic locus, whereas Chagala (1991) reported one dark-staining variable locus, accompanied by other less conspicuous zones of activity. We identified two polymorphic and two monomorphic loci. For LAP Eckert et al. (1981) reported three loci, whereas Chagala (1991) reported two. We scored two loci, but observed a third, inconsistent locus. For MDH Chagala (1991) reported four loci, whereas Bealieu and Simon (1994) reported three. We observed six clearly discernable loci in 191 trees. When present *Mdh2-2* overlapped monomorphic locus *Mdh3* and stained much darker than alternative genotypes. For PGI two loci have been reported in *P. strobus* (Eckert et al. 1981; Beaulieu & Simon 1994), whereas we consistently observed three variable loci. For PGM Eckert et al. (1981) and Beaulieu and Simon (1994) reported two loci, whereas Chagala (1991) reported one locus. We observed two dark-staining polymorphic loci and two faint but consistent monomorphic loci. The 6PGD enzyme has been variously reported in *P. strobus* as being a monomorphic enzyme by Eckert et al. (1981) and Beaulieu and Simon (1994) and as having two monomorphic loci (Chagala 1991). In contrast, we observed four polymorphic loci in our 191-tree analysis.

We calculated standard genetic diversity parameters (allele frequencies, allelic compliments, percent polymorphic loci, average number of alleles per locus) and Nei's (1978) unbiased estimates of mean observed and expected heterozygosity for pre- and postharvest stands from allozyme genotype data, using BIOSYS-1 (Swofford & Selander 1989). We used gene and genotype data to calculate "Gregorius multilocus genetic multiplicity and diversity measures" to further define genetic diversity losses. These include $G_M$, the multiplication product of all genotype combinations across all loci (Bergmann et al. 1990); *V*, genic diversity, which is the harmonic mean of the effective number of alleles per locus taken over all loci (Bergmann et al. 1990); $V_{gam}$, or hypothetical gametic diversity, which is the multiplication product of all the number of gametes theoretically available under linkage equilibrium (Gregorius 1987; Bergmann et al. 1990); and *LP*, or latent genetic potential, which is the difference between total number of alleles and effective number of alleles summed over all loci (Bergmann et al. 1990). In addition, we calculated expected and observed genotype additivity, $G_A$ (Rajora 1996), by summing the theoretical number of single-locus genotypes over all loci which could be expected from the allelic complement under Hardy-Weinberg expectations and by summing the actual single-locus genotypes present, respectively.

To determine effects of harvesting on alleles of different frequencies, we assigned alleles to one of four frequency classes: high ($p \geq 0.75$); intermediate ($0.75 > p \geq 0.25$); low ($0.25 > p \geq 0.01$); and rare ($p < 0.01$). For comparison we also classified alleles common ($p \geq 0.05$) and rare ($p < 0.05$), as suggested by Marshall and Brown (1975).

## Results

Comparison of pre- and postharvest gene pools indicated a substantial loss of genetic diversity as a result of harvesting (Table 3). Furthermore, the reduction was quite uniform between stands, suggesting that, except for heterozygosity, the effects were real and repeatable. Concurrent with a 75% reduction in the breeding population, mean number of alleles per locus was reduced by about 25% (24.6% and 24.7% in stands A and B, respectively), and the proportion of polymorphic loci in each stand dropped from about 75% to about 54% (51.9% and 55.6% in stands A and B, respectively). Removal of three-quarters of the trees in each stand did not significantly affect observed heterozygosity; there was actually a slight increase in observed heterozygosity in residual stand B, probably due to the chance retention of a number of highly heterozygous trees. Expected heterozygosities of both preharvest and postharvest stands were somewhat greater than observed heterozygosities, suggesting that some inbreeding had occurred in mating events giving rise to the natural stands.

Pre- and postharvest allele frequencies at 42 polymorphic loci are presented in the Appendix. Twelve loci (22.2%) were invariant in both stands (*Aat2, Adh4, Ald4, Dia3, Dia4, Idh3, Idh4, Mdh3, Mdh5, Mdh6, Pgm3, Pgm4*). In addition, *Ald1* and *6Pgd4* were monomorphic in stand A, whereas *Gdh4* was monomorphic in stand B. However, five additional loci (9.3%) were invariant in both postharvest stands (*Adh1, Gdh1, Gdh2,*

**Table 3. Measures of genetic diversity in preharvest and postharvest gene pools, Galloway Lake old-growth white pine.***

| | *Stand A* | | *Stand B* | |
|---|---|---|---|---|
| *Diversity parameter* | *Preharvest* | *Postharvest* | *Preharvest* | *Postharvest* |
| Number of trees | 96 | 25 | 95 | 23 |
| Total number of alleles over 54 loci | 121 | 91 | 128 | 96 |
| Mean number of alleles per locus | 2.24 (0.15) | 1.69 (0.11) | 2.37 (0.15) | 1.78 (0.11) |
| Number of polymorphic loci | 40 | 28 | 41 | 30 |
| Percent polymorphic loci | 74.1 | 51.9 | 75.9 | 55.6 |
| Mean heterozygosity (observed) | 0.125 (0.025) | 0.121 (0.024) | 0.126 (0.023) | 0.143 (0.024) |
| Mean heterozygosity (expected) | 0.149 (0.027) | 0.146 (0.027) | 0.157 (0.027) | 0.155 (0.027) |

**SE in parentheses.*

**Table 4. Distribution of alleles in allele frequency classes in preharvest and postharvest (residual) old-growth white pine stands.**

| | *Number of alleles (percentage of total number of alleles)* | | | | | |
|---|---|---|---|---|---|---|
| | *Stand A* | | | *Stand B* | | |
| | | *Postharvest (residual)* | | | *Postharvest (residual)* | |
| *Allele frequency class* | *Preharvest* | *Actual*[a] | *Retained*[b] *from preharvest stand* | *Preharvest* | *Actual*[a] | *Retained*[b] *from preharvest stand* |
| Total no. alleles | 121 | 91 | 91 | 128 | 96 | 96 |
| Four classes | | | | | | |
| High $p \geq 0.75$ | 43 (35.5) | 41 (45.0) | 43 (47.2) | 42 (32.8) | 46 (47.9) | 42 (43.7) |
| Intermediate $0.75 > p \geq 0.25$ | 20 (16.5) | 24 (26.4) | 20 (22.0) | 23 (18.0) | 14 (14.6) | 23 (24.0) |
| Low $0.25 > p \geq 0.01$ | 41 (33.9) | 26 (28.6) | 25 (27.5) | 49 (38.3) | 37 (38.5) | 29 (30.2) |
| Rare $p < 0.01$ | 17 (14.1) | 0 (0) | 3 (3.3) | 14 (10.9) | 0 (0) | 2 (2.1) |
| Two classes | | | | | | |
| Common $p \geq 0.05$ | 76 (62.8) | 80 (87.9) | 76 (83.5) | 76 (59.4) | 79 (82.3) | 76 (79.2) |
| Rare $p < 0.05$ | 45 (37.2) | 11 (12.1) | 15 (16.5) | 52 (40.6) | 17 (17.7) | 20 (20.8) |

[a] *Alleles were present in these frequency classes in the postharvest gene pool.*
[b] *Alleles were present in these frequency classes in the preharvest gene pools and were retained in the postharvest gene pools, but not necessarily in the same frequency classes.*

*Idh1, 6Pgd3*). Seven additional loci (*Adh3, Gdh4, Gdh5, Idh2, Lap2, Pgm1, Skdh1*) were monomorphic in postharvest stand A, and six additional loci (*Adh2, Aph2, Ald1, Ald2, Gdh3, Mdh1*) were monomorphic in postharvest stand B.

Preharvest stand A, with 121 alleles, was slightly less genetically diverse than preharvest stand B, with 128 alleles. However, allelic complements of both residual postharvest stands were reduced by about 25%, with 91 alleles remaining in postharvest stand A and 96 alleles in postharvest stand B. Both preharvest gene pools had similar distributions of allelic frequency classes (Table 4), with high- and low-frequency alleles each making up about one-third of the total allelic complement (35.5% and 33.9% in stand A, and 32.6% and 38% in stand B, respectively). Intermediate frequency and rare alleles in preharvest stand A were similarly distributed (16.5% and 14.1%, respectively). Nevertheless, there were more intermediate frequency alleles than rare alleles in preharvest stand B (17.8% and 11.6%, respectively). According to Marshall and Brown's (1975) classification, allozymes in both preharvest gene pools had similar distributions of common and rare allelic frequency classes (Table 4).

Losses of low frequency and rare alleles are presented in Table 5. In postharvest stand A about one-half of the 30 lost alleles were rare ($p < 0.01$) and one-half were low frequency alleles. In postharvest stand B about one-third of the 32 lost alleles were rare, the balance being low frequency alleles. When expressed as proportions of all rare and low frequency alleles, the losses from each frequency class are quite different. Eighty percent of all rare alleles were lost from the two gene pools, whereas about 40% of all low frequency alleles were lost (Table 5). Following Marshall and Brown's (1975) classification, about 64% of the rare alleles were lost (Table 5) with all the allele losses occurring only in the rare allele frequency class. All common alleles ($p \geq 0.05$) were retained in the postharvest stands (Tables 4 and 5). "Private" alleles, or those unique to either stand A or stand B, were especially vulnerable to harvest-induced elimination from the gene pools (Table 6).

Harvesting 75% of each stand had a large effect on residual-stand gene frequencies, and allele frequency changes followed the same general patterns in stands A and B (Appendix). Twenty-nine high-frequency alleles in each of the preharvest stands changed very slightly (av-

**Table 5. Allele losses in old-growth white pine stands due to harvesting.**

| *Allele losses* | *Stand A* | *Stand B* |
|---|---|---|
| Total number (%) | 30 (24.8) | 32 (25.0) |
| Four allele frequency classes[a] | | |
| Number (%) rare | 14 (82.4) | 12 (80.0) |
| Number (%) low | 16 (39.0) | 20 (40.8) |
| Number (%) intermediate and high | 0 (0) | 0 (0) |
| Alleles lost of total alleles lost in different frequency classes (%) | | |
| Rare | 46.7 | 37.5 |
| Low | 53.3 | 62.5 |
| Intermediate and high | 0.0 | 0.0 |
| Alleles lost of the total alleles detected (%) | | |
| Rare | 11.6 | 9.4 |
| Low | 13.2 | 15.6 |
| Two allele frequency classes[b] | | |
| Number (%) rare | 30 (66.7) | 32 (61.5) |
| Rare alleles lost of the total alleles (%) | 24.8 | 25.0 |
| Number (%) common | 0 (0) | 0 (0) |

[a] *High* $p \geq 0.75$, *intermediate* $0.75 > p \geq 0.25$; *low* $0.25 < p \geq 0.01$; *rare* $p < 0.01$.
[b] *Common* $p \geq 0.05$; *rare* $p < 0.05$.

**Table 6. Number of alleles[a] unique and common to old-growth white pine stands A and B and retained after harvesting.**

| | Number of alleles (%) | | |
|---|---|---|---|
| *Alleles* | *Total* | *Retained after harvesting* | *Lost after harvesting* |
| Unique to stand A[b] | 13 (9.2) | 2 (1.4) | 11 (7.8) |
| Unique to stand B[b] | 20 (14.2) | 6 (4.3) | 14 (9.9) |
| Common to stands A and B[b] | 108 (76.6) | | |
| Retained in stands A and B[b] | | 80 (56.7) | |
| Lost from stands A and B[b] | | | 9 (6.4) |
| Lost from stand A only[c] | | | 10 (8.3) |
| Lost from stand B only[d] | | | 9 (7.0) |

[a]*For specific alleles retained and lost and their frequencies, see Appendix.*
[b]*Percentage of 141 alleles detected in both stands A and B.*
[c]*Percentage of 121 alleles detected in stand A.*
[d]*Percentage of 128 alleles detected in stand B.*

erage of 5%) after harvest. Frequencies of intermediate alleles fluctuated more widely between pre- and postharvest gene pools. Harvest-induced gene frequency changes in low-frequency alleles were much higher than intermediate- or high-frequency alleles (the average change was 87% in stand A and 75% in stand B). Frequencies of the surviving rare alleles increased by 300% and 340% in stands A and B, respectively.

Harvesting caused major changes in most of the Gregorius genetic multiplicity and diversity measures and genotype additivity (Table 7), and as with most of the standard genetic diversity parameters (Table 3), both stands responded quite similarly. Because of allelic losses, expected and observed postharvest $G_M$ were very small percentages of preharvest values. The $V_{gam}$ was reduced by about 40% in each stand (39.8% and 40.4% in stands A and B, respectively), whereas about 50% of *LP* was lost from preharvest levels (52% and 54% for stands A and B, respectively). Losses in expected and observed $G_A$ ranged from 30% to 40% (38.3% and 29.7% for expected and observed, respectively, in stand A, and 38.6% and 29.4% for stand B). Genic diversity, *V*, like heterozygosity, was not greatly influenced by allelic losses.

## Discussion

We have documented a reduction in allelic richness of about 25% due to harvesting in two old-growth white pine stands. Allelic losses amounted to 80% of all rare ($p < 0.01$) alleles and 40% of all low frequency alleles in the two stands. Low-frequency allele losses are more significant when it is recognized that this allele class accounted for about 36% of all assayed alleles in each stand, and in preharvest stands, low frequency alleles were as numerous as were high frequency alleles. Although the genetic makeup of each of the examined stands was different, response to harvesting was quite uniform between stands. This suggests genetic diversity losses of 25% or more may be common when forests of this type are harvested at these intensities.

These allele losses are of similar magnitude to those described from comparisons of phenotypic seed orchard selections and natural populations of white spruce (*Picea glauca* Moench Voss) (Cheliak et al. 1988), loblolly pine (*Pinus taeda* L.) (Hamrick 1991), and Douglas-fir (El-Kassaby & Ritland 1996). Our results, however, are quite different from Neale's (1985) findings in old-growth, coastal Douglas-fir, where essentially no differences in genetic diversity measures were found between residual gene pools resulting from shelterwood cuts and gene pools from adjacent, uncut control stands. Neale's (1985) objective was to generate equal random samples of study trees to compare common alleles in uncut and harvested stands and not to census contiguous stand plots for genetic diversity before and after harvest. Consequently, Neale (1985) reported no rare alleles, probably as a result of sampling probabilities (Gregorius 1980). In contrast, when we censused old-growth white pine stands by analyzing every tree contributing to the gamete pool, we found that proportions of high and low

**Table 7. Gregorius multilocus genetic multiplicity and diversity measures and genotype additivity for pre- and postharvest old-growth white pine gene pools.**

| | Stand A | | Stand B | |
|---|---|---|---|---|
| *Parameter** | *Preharvest* | *Postharvest* | *Preharvest* | *Postharvest* |
| $G_M$ (expected) | $2.5821 \times 10^{26}$ | $7.32057 \times 10^{15}$ | $4.91827 \times 10^{28}$ | $7.02775 \times 10^{17}$ |
| $G_M$ (observed) | $2.17949 \times 10^{20}$ | $3.42843 \times 10^{12}$ | $1.20367 \times 10^{21}$ | $2.1671 \times 10^{13}$ |
| $V$ | 1.270 | 1.254 | 1.285 | 1.267 |
| $V_{gam}$ | 37236 | 22416 | 66558 | 39066 |
| *LP* | 52.44 | 24.39 | 58.63 | 27.60 |
| $G_A$ (expected) | 227 | 140 | 246 | 151 |
| $G_A$ (observed) | 155 | 109 | 160 | 113 |

*$G_M$ = *multilocus genotype multiplicity (Bergmann et al. 1990);* V = *genic diversity (Gregorius 1987);* $V_{gam}$ = *hypothetical gametic diversity (Gregorius 1987);* LP = *latent genetic potential (Bergmann et al. 1990);* $G_A$ = *genotype additivity (Rajora 1996).*

frequency alleles were roughly equal, as were intermediate and rare frequency alleles. Another factor that may contribute to differences in measurable impacts on white pine and Douglas-fir gene pools is that there may be fundamental differences in the way the two species are organized genetically at the population level.

Expected heterozygosities in the preharvest old-growth white pine stands were somewhat lower than those reported for other forest tree species (Hamrick et al. 1992). This may be due to the inclusion of data from all 54 loci in our heterozygosity calculations, because analyses with both monomorphic and polymorphic loci provide more conservative heterozygosity estimates of genetic diversity than those using only polymorphic loci. Results from this study confirm, for undisturbed old-growth white pine populations, the general observation that allelic richness measures are more useful than allelic evenness measures (e.g., heterozygosity) when quantifying effects of perturbations on gene pools (Marshall & Brown 1975; Leberg 1992). Although heterozygosity measures are widely-used descriptors of genetic diversity, in our study they did not follow the reduction in allelic complements due to harvesting. Mean observed heterozygosity actually increased after harvest in stand B by about 12%, perhaps as a result of an increased proportion of residual trees in the postharvest stand with loci heterozygous for high and intermediate frequency alleles. This may reflect the fact that stand B was somewhat more genetically diverse than stand A, both before and after harvest. Leberg (1992) reported increased heterozygosity in post-bottleneck populations of eastern mosquitoefish (*Gambusia holbrooki*) and suggested that random drift could account for this increase in progeny populations. In these old-growth white pine populations, however, heterozygosity was maintained or increased in the bottlenecked residual stand, suggesting that harvest-induced gene frequency changes were responsible, rather than random drift following sexual regeneration, as reported by Leberg (1992).

The number of private or unique alleles in each stand is quite high when compared to levels reported for other white pine populations (Beaulieu & Simon 1994) and other species (Cheliak et al. 1988; El-Kassaby & Ritland 1996; Neale 1985; Yazdani et al. 1985). We suspect this may be a result of the large numbers of trees analyzed from each stand and the large number of polymorphic loci assayed and may be indicative of population substructuring and local adaptation at the landscape level. The loss of private alleles from both stands gives concern for the integrity of locally-adapted gene pools after harvesting. Genetic markers such as allozymes have generally been considered to be selectively neutral, and taken individually, do not appear to be well correlated with general genomic diversity changes (Mitton & Pierce 1980; Chakraborty 1981). When a large number of loci are considered, however, as in this study, results may be more indicative of general trends occurring in allozyme-linked loci of selective value across the genome.

The actual measurable losses of alleles have even greater significance if allozyme loci are not selectively neutral, but play a part in fitness and adaptability, as Müller-Starck (1985), Bergmann et al. (1990), and Bush and Smouse (1992) have suggested. Under an adaptive gene action hypothesis, the low and rare frequency allozyme alleles in a population represent much of the genetic potential required for population adaptation to long-term environmental changes because alleles of higher frequencies have probably been selected for current or recent past environments. Low levels of latent genetic potential have been correlated with forest decline in northern and central populations of European silver fir (*Abies alba* Mill.), whereas high levels appear to be correlated with healthy southern European populations (Bergmann et al. 1990). We have determined that the harvesting intensity in the current study has reduced the latent genetic potential of the residual gene pools to about one-half of that initially present in the preharvest gene pools. Furthermore, this reduction is roughly equivalent to that reported in north and central populations in contrast to southern populations of European silver fir (Bergmann et al. 1990). Reductions in the levels of $G_M$, $V_{gam}$, and $G_A$ also suggest a reduction in long-term evolutionary potential. These reductions are comparable to the differences found between Norway spruce (*Picea abies* [L.] Karst.) populations that are tolerant and sensitive to airborne pollutants (Raddi et al. 1994) and to differences between pollution tolerant and sensitive beech clones (*Fagus sylvatica* L.) (Müller-Starck 1985).

Studies of parent and progeny generations in several tree species indicate that progeny gene and genotype frequencies usually follow Hardy-Weinberg expectations (Neale 1985; Roberds & Conkle 1984; Yazdani et al. 1985). If this situation is valid for regenerating, harvested old-growth white pine stands, gene frequency changes due to harvesting suggest that the progeny resulting from the harvested residual stands may be quite different from undisturbed preharvest stands.

We do not know whether the affected alleles have selective value, and we cannot suggest what the changing genotype frequencies may mean for the regenerating forest. Also, because the sample stands have not yet regenerated, we have not been able to determine to what extent the residual parental stand genetic diversity is expressed in the replacement stand. There is evidence from loblolly pine that some rare alleles are deleterious (Bush & Smouse 1992). If this is the case in white pine, there may be some eugenic effects from eliminating 80% of the rare alleles from the breeding population. It is also possible, however, that new, useful mutations may be present in these gene pools and are currently at very low frequencies. Müller-Starck (1985) has presented evidence for the adaptive value of certain rare alleles in environmentally-stressed beech populations. In light of the need to maintain genetic diversity for long-term evolution in changing environments, and recognizing our current lack of understanding of the adaptive value of these low and rare frequency alleles, it seems prudent to ensure that the gene pools remain intact and that natural selection be allowed to remove deleterious alleles during the lifecycle of the progeny generation.

We do not know to what extent gene migration will ameliorate the genetic losses we have measured in these harvested stands. Gene flow is reported to be very high in eastern white pine (Beaulieu & Simon 1994), and it is conceivable that genetic diversity in naturally-regenerated populations may be as high as preharvest parental stands due to pollen migration from surrounding stands. Conifer seed orchard pollen contamination studies indicate that many factors contribute to effective gene flow, however, including synchronous flowering biology of individuals and populations, density of background pollen, seasonal weather patterns, and distance from outside pollen sources (Friedman & Adams 1985; El-Kassaby & Ritland 1986; Wheeler & Jech 1986; Harju & Muona 1989; Paule 1991). All surrounding stands within 3 km of the study stands have been harvested in similar manner, so reintroduction of lost alleles from surrounding stands is problematical.

It is also likely that the effective breeding population of each residual stand is actually smaller than the census population because some of the residual trees are effectively non-contributors to the gene pool. We do not know how the changes in stand density will affect mating systems of the residual trees, and in turn, how the remaining genetic diversity will be expressed in progeny populations. It is possible that even greater genetic diversity losses may result in stands where current harvesting policies reduce residual stand numbers below the approximate 50 stems per hectare as experienced in these study stands. Despite the many unknowns, it is clear that in order to maintain the legacy of these remaining intact old-growth gene pools, old-growth stands must be carefully regenerated before any significant genetic erosion due to human activity occurs.

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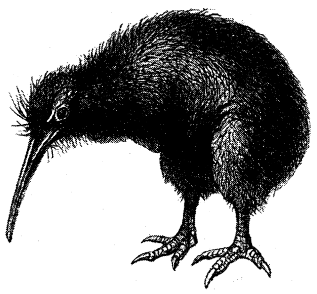


## Appendix

**Preharvest and postharvest allele frequencies at polymorphic loci in old-growth white pine gene pools (stands).**

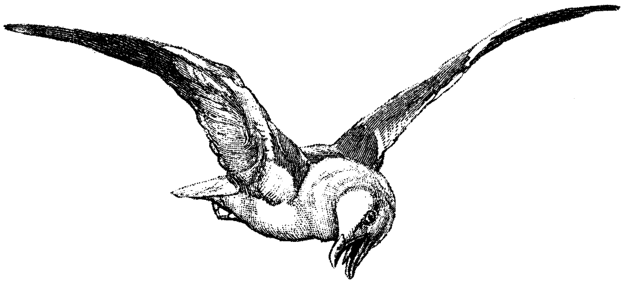
| | | *Stand A* | | *Stand B* | |
|---|---|---|---|---|---|
| *Locus* | *Allele* | *Preharvest* | *Postharvest* | *Preharvest* | *Postharvest* |
| *Aat 1* | *1* | 0.990 | 0.980 | 0.926 | 0.870 |
| | *2* | — | — | 0.005 | — |
| | *0* | 0.010 | 0.020 | 0.068 | 0.130 |
| *Aat 3* | *1* | 0.547 | 0.600 | 0.411 | 0.370 |
| | *2* | 0.443 | 0.400 | 0.589 | 0.630 |
| | *0* | 0.010 | — | — | — |
| *Aat 4* | *1* | 0.552 | 0.620 | 0.421 | 0.391 |
| | *2* | 0.443 | 0.380 | 0.579 | 0.609 |
| | *0* | 0.005 | — | — | — |
| *Adh 1* | *1* | 0.005 | — | — | — |
| | *2* | 0.026 | — | — | — |
| | *3* | 0.969 | 1.000 | 0.995 | 1.000 |
| | *4* | — | — | 0.005 | — |
| *Adh 2* | *1* | 0.036 | 0.080 | — | — |
| | *2* | 0.938 | 0.900 | 0.958 | 1.000 |
| | *3* | 0.026 | 0.020 | 0.011 | — |
| | *0* | — | — | 0.032 | — |
| *Adh3* | *1* | 0.026 | — | 0.026 | 0.109 |
| | *2* | 0.974 | 1.000 | 0.974 | 0.891 |
| *Aph 1* | *1* | 0.057 | 0.020 | 0.011 | — |
| | *2* | 0.349 | 0.440 | 0.532 | 0.500 |
| | *3* | 0.042 | 0.120 | 0.200 | 0.174 |
| | *4* | 0.146 | 0.140 | 0.037 | 0.087 |
| | *5* | 0.406 | 0.280 | 0.221 | 0.239 |
| *Aph 2* | *1* | 0.005 | — | 0.005 | — |
| | *2* | 0.953 | 0.980 | 0.995 | 1.000 |
| | *3* | 0.042 | 0.020 | — | — |
| *Ak 2* | *1* | 0.380 | 0.080 | 0.089 | 0.152 |
| | *2* | 0.620 | 0.920 | 0.911 | 0.848 |
| *Ald 1* | *1* | 1.000 | 1.000 | 0.989 | 1.000 |
| | *0* | — | — | 0.011 | — |
| *Ald 2* | *1* | 0.984 | 0.960 | 0.989 | 1.000 |
| | *2* | 0.016 | 0.040 | 0.011 | — |
| *Ald 3* | *1* | 0.109 | 0.340 | 0.268 | 0.261 |
| | *2* | 0.891 | 0.660 | 0.564 | 0.217 |
| | *3* | — | — | 0.168 | 0.522 |
| *Dia 1* | *1* | 0.599 | 0.720 | 0.632 | 0.761 |
| | *2* | 0.401 | 0.280 | 0.342 | 0.217 |
| | *0* | — | — | 0.026 | 0.022 |
| *Dia 2* | *1* | 0.599 | 0.720 | 0.647 | 0.761 |
| | *2* | 0.401 | 0.280 | 0.353 | 0.239 |
| *Dia 5* | *1* | 0.130 | 0.300 | 0.058 | 0.152 |
| | *2* | 0.870 | 0.700 | 0.942 | 0.848 |
| *Gdh 1* | *1* | 0.005 | — | — | — |
| | *2* | 0.995 | 1.000 | 0.995 | 1.000 |
| | *3* | — | — | 0.005 | — |
| *Gdh 2* | *1* | 0.969 | 1.000 | 0.978 | 1.000 |
| | *2* | 0.021 | — | 0.011 | — |
| | *0* | 0.010 | — | 0.011 | — |
| *Gdh 3* | *1* | 0.031 | 0.120 | 0.026 | — |
| | *2* | 0.958 | 0.880 | 0.953 | 1.000 |
| | *0* | 0.010 | — | 0.021 | — |

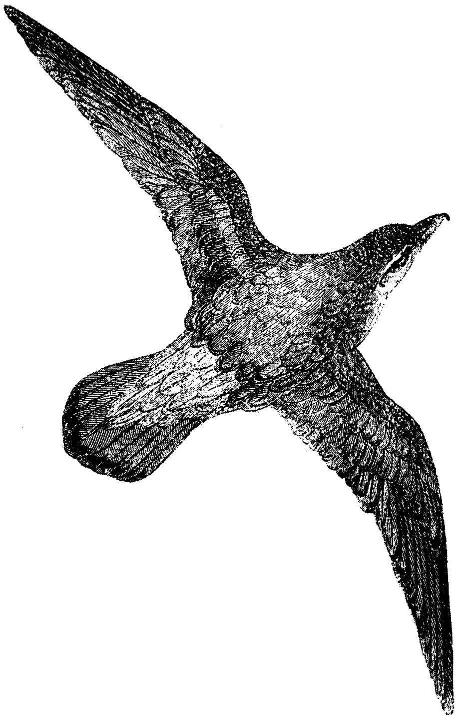
## Appendix Continued.

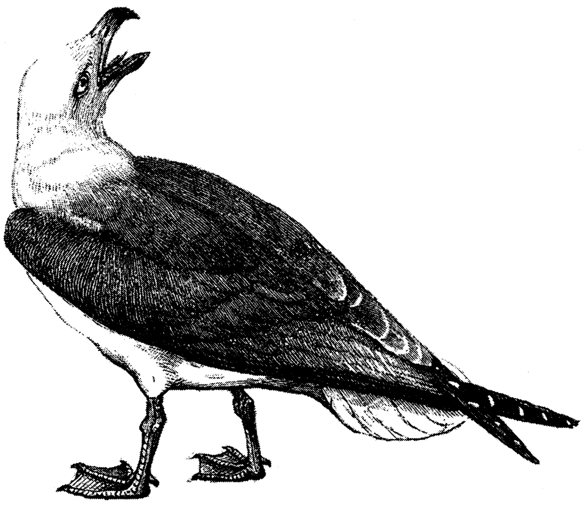
| | | *Stand A* | | *Stand B* | |
|---|---|---|---|---|---|
| *Locus* | *Allele* | *Preharvest* | *Postharvest* | *Preharvest* | *Postharvest* |
| *Gdh 4* | *1* | 0.995 | 1.000 | 1.000 | 1.000 |
| | *2* | 0.005 | — | — | — |
| *Gdh 5* | *1* | 0.984 | 1.000 | 0.984 | 0.978 |
| | *2* | 0.016 | — | 0.016 | 0.022 |
| *Idh 1* | *1* | 0.005 | — | — | — |
| | *2* | 0.948 | 1.000 | 0.984 | 1.000 |
| | *3* | 0.042 | — | 0.011 | — |
| | *4* | 0.005 | — | 0.005 | — |
| *Idh 2* | *1* | — | — | 0.016 | 0.043 |
| | *2* | 0.005 | — | 0.021 | 0.022 |
| | *3* | 0.995 | 1.000 | 0.963 | 0.935 |
| *Lap 1* | *1* | 0.021 | 0.060 | 0.016 | — |
| | *2* | 0.964 | 0.920 | 0.958 | 0.935 |
| | *3* | 0.010 | — | 0.010 | 0.043 |
| | *0* | 0.005 | 0.020 | 0.016 | 0.022 |
| *Lap 2* | *1* | — | — | 0.010 | — |
| | *2* | 0.974 | 1.000 | 0.979 | 0.978 |
| | *3* | 0.016 | — | 0.011 | 0.022 |
| | *0* | 0.010 | — | — | — |
| *Mdh 1* | *1* | 0.990 | 0.980 | 0.989 | 1.000 |
| | *0* | 0.010 | 0.020 | 0.011 | — |
| *Mdh 2* | *1* | 0.698 | 0.720 | 0.647 | 0.717 |
| | *2* | 0.161 | 0.180 | 0.274 | 0.196 |
| | *3* | 0.141 | 0.100 | 0.079 | 0.087 |
| *Mdh 4* | *1* | — | — | 0.005 | — |
| | *2* | 0.958 | 0.940 | 0.979 | 0.957 |
| | *3* | 0.042 | 0.060 | 0.016 | 0.043 |
| *Me* | *1* | 0.698 | 0.720 | 0.647 | 0.717 |
| | *2* | 0.161 | 0.180 | 0.274 | 0.196 |
| | *3* | 0.141 | 0.100 | 0.079 | 0.087 |
| *Mnr 1* | *1* | 0.625 | 0.720 | 0.632 | 0.761 |
| | *2* | 0.375 | 0.280 | 0.342 | 0.217 |
| | *0* | — | — | 0.026 | 0.022 |
| *Mnr 2* | *1* | 0.625 | 0.720 | 0.632 | 0.761 |
| | *2* | 0.375 | 0.280 | 0.347 | 0.239 |
| | *0* | — | — | 0.021 | — |
| *Mnr 3* | *1* | 0.005 | 0.020 | 0.079 | 0.152 |
| | *2* | 0.995 | 0.980 | 0.911 | 0.848 |
| | *0* | — | — | 0.011 | — |
| *Pgi 1* | *1* | 0.005 | — | — | — |
| | *2* | 0.063 | — | 0.026 | 0.022 |
| | *3* | 0.917 | 0.980 | 0.921 | 0.978 |
| | *4* | 0.005 | — | 0.048 | — |
| | *5* | 0.005 | 0.020 | 0.005 | — |
| | *0* | 0.005 | — | — | — |
| *Pgi 2* | *1* | 0.010 | — | 0.037 | — |
| | *2* | 0.099 | 0.080 | 0.079 | 0.130 |
| | *3* | — | — | 0.005 | — |
| | *4* | 0.885 | 0.920 | 0.847 | 0.848 |
| | *5* | 0.005 | — | 0.032 | 0.022 |
| *Pgi 3* | *1* | 0.031 | 0.020 | 0.042 | 0.022 |
| | *2* | 0.948 | 0.920 | 0.910 | 0.956 |
| | *3* | — | — | 0.037 | 0.022 |
| | *0* | 0.021 | 0.060 | 0.011 | — |

## Appendix Continued.

| Locus | Allele | Stand A Preharvest | Stand A Postharvest | Stand B Preharvest | Stand B Postharvest |
|---|---|---|---|---|---|
| *Pgm 1* | *1* | 0.016 | — | 0.005 | 0.022 |
| | *2* | 0.984 | 1.000 | 0.995 | 0.978 |
| *Pgm 2* | *1* | 0.182 | 0.160 | 0.300 | 0.304 |
| | *2* | 0.761 | 0.780 | 0.684 | 0.696 |
| | *3* | 0.057 | 0.060 | 0.011 | — |
| | *0* | — | — | 0.005 | — |
| *6Pgd1* | *1* | 0.021 | 0.040 | 0.047 | 0.109 |
| | *2* | 0.979 | 0.960 | 0.937 | 0.891 |
| | *3* | — | — | 0.011 | — |
| | *0* | — | — | 0.005 | — |
| *6Pgd2* | *1* | 0.010 | — | 0.016 | 0.022 |
| | *2* | 0.146 | 0.280 | 0.484 | 0.456 |
| | *3* | 0.844 | 0.720 | 0.500 | 0.522 |
| *6Pgd3* | *1* | 0.005 | — | 0.005 | — |
| | *2* | 0.995 | 1.000 | 0.995 | 1.000 |
| *6Pgd4* | *1* | 1.000 | 1.000 | 0.995 | 0.978 |
| | *2* | — | — | 0.005 | 0.022 |
| *Skdh 1* | *1* | 0.016 | — | 0.026 | 0.022 |
| | *2* | 0.984 | 1.000 | 0.974 | 0.978 |
| *Skdh 2* | *1* | 0.365 | 0.600 | 0.232 | 0.217 |
| | *2* | — | — | 0.005 | — |
| | *3* | 0.630 | 0.400 | 0.763 | 0.783 |
| | *4* | 0.005 | — | — | — |







# Attachment 09

Pisgah National Forest National Forests in North Carolina
Transportation System Analysis Process (TAP) Report –
October 2012

# Pisgah National Forest
# National Forests in North Carolina
# Transportation System Analysis
# Process (TAP) Report

October 2012

Recommended by:
Tina Tilley, District Ranger, Appalachian RD
John Crockett, District Ranger, Grandfather RD
Derek Ibarguen, District Ranger, Pisgah RD

Reviewed by:
Kristin Bail, Forest Supervisor
National Forests in North Carolina
USDA Forest Service
Southern Region

Pisgah National Forest
Unit Scale Transportation System Analysis Process (TAP) Report

Table of Contents

## Executive Summary

Objectives of Forest-Wide Transportation System Analysis Process (TAP)

The objectives of Forest-Wide TAP conducted over the past year were to:

- identify key issues related to the Pisgah National Forest*'s* transportation system
- identify benefits, problems and risks related to the Pisgah National Forest*'s* transportation system;
- identify management opportunities related to the existing transportation system to suggest for future consideration as National Environmental Policy Act (NEPA) decisions (examples included items such as road decommissioning within priority watersheds and needed aquatic passage improvement projects);
- create a map to inform the identification of the future Minimum Road System (MRS);
- indicate the location of unneeded roads and possible new road needs.

(Note: Forest Service regulations at 36 CFR 212.5(b)(1) require the Forest Service to identify the minimum road system needed for safe and efficient travel and for administration, utilization, and protection of National Forest System (NFS) lands.)

Analysis Participants

The TAP was conducted by an interdisciplinary team with extensive internal participation, and limited participation by partners and the general public. The primary participants were:

| | | | |
|---|---|---|---|
| Josh Martin | Team Lead | Cleve Fox | FMO |
| | | Greg Philipp | FMO |
| Tina Tilley | District Ranger | Patrick Scott | FMO |
| John Crockett | District Ranger | | |
| Derek Ibarguen | District Ranger | Cliff Northrop | Civil Engineer |
| | | Chris Williams | Biologist |
| Lynn Hicks | Eng. HER | Dave Danley | Botanist |
| Brady Dodd | Soil & Water Specialist | Scott Ashcraft | Archeologist |
| David McFee | Operations Forester | Amber Vanderwolf | GIS |
| Ted Oprean | Silviculturist | | |
| Matt Keyes | TMA | | |
| Lorie Stroup | Wildlife & Fisheries Specialist | | |

Overview of the Pisgah National Forest's Road System

The Pisgah National Forest's road system currently comprises some 885 miles, providing access to approximately 512,670 net acres of national forest, as well as to interspersed private tracts and nearby local communities. The system supports both recreation and resource management. It is comprised of a combination of old "public" roads, roads constructed to access timber sales and subsequent silvicultural activities, roads constructed to access recreation areas, and a variety of other routes. These range from double lane paved roads to single lane gravel or native surface roads that may be useable by passenger cars, to high clearance routes, to travel ways that are closed for periods of time greater than one year. Funding for the construction or reconstruction of all types was generally provided either by congressional appropriations, or authorized as a component of a timber sale. Maintenance funding is primarily by congressional appropriations, although timber sales generally funds any maintenance required during the life of a particular sale operation.

Key Issues, Benefits, Problems and Risks, and Management Opportunities Identified

- Current appropriations and supplemental revenue sources are not sufficient to adequately maintain the Pisgah National Forest's 885 mile Road System as currently configured. Without changes, the existing road system would require an annual expenditure of approximately $3.4 million to maintain the system to Forest Service Standards. Only about $426,300 dollars are currently available, (FY12 road maintenance budget), resulting in a shortfall of about $3 million, or 88% of the total dollars needed.
- There is substantial system mileage which primarily serves either as access to private inholdings, or as general access to adjacent communities (approximately 240.25 miles, or 27% of the total). As opportunities allow, jurisdiction and maintenance costs should be considered for transfer to the most appropriate entity in order to allow the limited maintenance funding to be applied most effectively to the system roads of the Pisgah National Forest.
- Certain roads, particularly those located relatively low in the watersheds, may be causing undue stress to water quality and associated aquatic organisms, especially if they cannot be regularly and properly maintained. This is particularly the case in watersheds that are classified as "impaired." There are zero miles of forest roads located on impaired watersheds on the Pisgah National Forest. In some cases there appear to be opportunities to decrease the total system maintenance costs, while at the same time better protecting water quality by decommissioning those roads with the highest risk and least benefit. Approximately 64 miles have been identified by the TAP to be considered for decommissioning or long term storage.
- There are a number of roads that will most likely be needed at some time in the future, but which do not appear to be needed for actions currently being proposed. Storage of these roads (closure for at least a year, with only custodial maintenance

provided) should be strongly considered. The TAP analysis suggests that about 90.32 miles should be considered for conversion to storage and custodial maintenance only until needed.

- In order to meet budgetary limitations some roads currently opened year round will need to be identified to be considered for seasonal closure (50.24 miles); and some roads currently maintained for passenger car use will need to be identified to be considered for conversion to high clearance use only (29.28 miles).
- Relatively high road densities may be impacting some sensitive wildlife species in a few specific areas of the forest. Overall, however, road densities do not exceed those allowed by the forest plan. As configured the overall road density, exclusive of non-FS jurisdiction roads, is 1.11 miles/square mile, and the open road density is .53 miles per square mile.
- Several roads or portions of roads may have to be closed due to insufficient bridge replacement funding. There are 86 bridges and major culverts on the Forest, of which 53 appear to be load restricted or otherwise deficient
- Opportunities should be sought to increase road maintenance revenues where possible through the use of stewardship contracts and partnerships, including volunteer groups, such as hunters, equestrian organizations, ATV user groups and others.

Comparison of Existing System to Minimum Road System as Proposed by the TAP

Refer to Appendix F for a summary of proposed changes to the existing road system suggested by the TAP, as information available to frame future NEPA analysis and decisions.

Next Steps

- TAP recommendations will be used to inform NEPA decisions, many of which will eventually be implemented in conjunction with various restoration projects on the Forest.
- Prior to implementing these recommendations, NEPA determinations will be conducted at the appropriate scale, using the TAP to inform issues, particularly cumulative effects and affordability.
- The road system should be revisited with an updated forest-wide TAP, probably on about a 10 year cycle, with the next one due by perhaps the year 2025.

## Context

Alignment with National and Regional Objectives

Sub-Part "A" Travel Analysis is required by the 2005 Travel Management Rule (36 CFR 212.5). Forest Service Manual 7712 and Forest Service Handbook 7709.55-Chapter 20 provide specific direction, including the requirement to use a six step interdisciplinary, science-based process to ensure that future decisions are based on an adequate consideration of environmental, social and economic impacts of roads. A letter from the Chief of the Forest Service dated March 29, 2012 was issued to replace a November 10, 2010 letter previously issued on the same topic. It reaffirms agency commitment to completing travel analysis reports for Subpart A of the travel management rule by 2015, and also provides additional national direction related to this work, addressing process, timing and leadership expectations. The letter requires documentation of the analysis by a travel analysis report, which includes a map displaying the existing road system and possible unneeded roads. It is intended to inform future proposed actions related to identifying the minimum road system. The TAP process is designed to work in conjunction with other frameworks and processes, the results of which collectively inform and frame future decisions executed under NEPA. This letter, including a diagram which further illustrates the relationship between NEPA and TAP is included in Appendix G.

The document entitled "Sub-Part "A" Travel Analysis (TAP), Southern Region Expectations, Revised to align with 2012 Chief's Letter" and attached in Appendix G, supplements the national direction for Forest Scale TAPs developed for the Southern Region.

Coordination with Forest Plan

The current Forest Plan for the Pisgah National Forest*'s* was adopted in 1994. It provides specific direction for overall management of the Pisgah National Forest. The Forest-wide TAP tiers to the Pisgah National Forest *s* Forest Plan by informing future NEPA actions that implement the Forest Plan and have transportation components. The TAP has been informed by the Watershed Condition Framework, and likewise, the TAP is intended to inform future forest restoration activities, including watershed restoration.

Budget and Political Realities

The roads located on the Pisgah National Forest are a combination of historic trails that have undergone improvement over the years, roads that were built in the decades of the sixties, seventies and eighties to access timber sales, roads constructed for access to communities, either internal or adjacent to the Forest, roads constructed by recreational users, and roads constructed or otherwise acquired through a variety of means to comprise the current system. As is the case for much of the rest of the infrastructure on the Forest, funding has been inadequate to properly maintain all of the Forest's roads and bridges. In some cases these roads and bridges have become superfluous to our administrative needs, and many no longer meet public needs either.

Changes are becoming inevitable, being driven both by the budget as well as by the need to have the most efficient and effective transportation system on the ground as possible, and no more. The TAP process is an attempt to begin to identify a proposed "minimum road system" (MRS) which will only come into place as NEPA decisions are made and then actual on-the-ground decisions are implemented. The MRS will probably change over time as well, as public needs and financial resources change. Therefore it is expected that new Forest-wide TAP analyses will continue to be needed, probably on about a 10 year cycle.

Anticipated 2012 Transportation Bill Effects (to be supplied later)

Alignment with Watershed Condition Framework (WCF)

Along with the other national forests across the country, Pisgah National Forest recently conducted an analysis of its watersheds, categorized them as to their condition and prioritized them for future efforts at improvement. Three categories were identified: Class 1 – Functioning Properly, Class 2 – Functioning at Risk, and Class 3 – Impaired Function. These classifications were performed on watersheds at the 6th order hydrologic unit classification (HUC) according to standard procedures described in the "Watershed Condition Framework" technical guide, found at http://www.fs.fed.us/publications/watershed/Watershed_Condition_Framework.pdf. It was determined that 2 watersheds on the Pisgah National Forest are Class 1, 28 are Class 2 and zero are Class 3. A map showing the location of these can be found in the Appendices. Armstrong Creek watershed was selected as a priority watershed for focus work in the next five to ten years. The priority watershed may also be found on the map in Appendix I.

The forest-wide TAP analysis was heavily informed by the WCF. For example, roads located near streams within impaired watersheds, and especially priority impaired watersheds, were particularly considered as possible decommissioning candidates. Similarly, continuing watershed improvement work is intended to be informed in the future by the TAP.

## Overview of the Pisgah National Forest and the supporting Transportation System

General Description of the Pisgah National Forest Land Ownership Patterns, Land Use and Historic Travel Routes

The Pisgah National Forest is comprised of 512,670 acres, occupying almost 48% of the proclamation boundary. Almost all is forested, with about 152,580 acres (or 30 %) being Wilderness or otherwise classified as Roadless, and 360,090 acres (or 70 %) being available for active forest management. Interspersed within the proclamation boundary, and adjacent to the National Forest are several large tracts managed as TIMOs (Timber Investment Management Organizations) or REITs (Real Estate Investment Trusts) as well as some scattered large forest industry tracts, some small farms and a variety of other ownership types. There are a few small communities within the proclamation boundary as well, the larger ones being Hot Springs, Bakersville, Elk Park and Roseboro. When the land came under the ownership of the Pisgah National Forest it was riddled with a legacy of historic travel routes that were primarily located low in the watersheds, alongside stream channels, presumably as these were the simplest locations on which to construct primitive travel ways. Over the past few decades the Pisgah National Forest has been slowly working towards relocating many of these roads up the slopes and away from the streams.

The lands of the Pisgah National Forest are administered by three ranger districts, Appalachian, Grandfather, and Pisgah Ranger Districts.

Table 1: Acres Administered by District

| District | Acres | Portion that is Roadless |
|---|---|---|
| Appalachian | 161,511 | 28,635 |
| Grandfather | 192,540 | 50,066 |
| Pisgah | 158,619 | 20,654 |
| Totals | 512,670 | 83,628 |

Table 2: Developed recreation areas on the Forest

| Appalachian Ranger District | Grandfather Ranger District | Pisgah Ranger District |
|---|---|---|
| Black Mountain Campground | Boone Fork Campground | Davidson River Recreation Area |
| Carolina Hemlocks Campground | Curtis Creek Campground | Lake Powhatan Recreation Area |
| Harmon Den Horse Camp | Mortimer Campground | North Mills River |
| Rocky Bluff Campground | | Sunburst Campground |
| Briar Bottom Group Camp | | Cove Creek Campground |
| Silvermine Group Camp | | Kuykendall Campground |
| Roan Mountain Recreation Area | | Wash Creek |
| Murray Branch Picnic Area | | White Pines |
| | | Cradle of Forestry |
| | | Sliding Rock |

Dispersed recreation is allowed throughout the Pisgah National Forest with only limited exceptions. Also there are 944 miles of trails (APP 264, GRF 300, PIS 380), supporting a variety of uses, including OHVs, equestrian, biking, pedestrian, and mixed use. Motor vehicles are restricted to those roads shown on the official Motor Vehicle Use Map (MVUM) included in Section H, Appendix C.

Description of the Pisgah National Forest's Transportation System

Interstate Highways 40 and 26, several Federal and State highways, including the Blue Ridge Parkway, State Highways 267, 64, 19E, 19W, 321, and 25/70, and quite a number of roads under state jurisdiction traverse various parts of the Pisgah National Forest. Some of these roads comprise a portion of the 247.26 miles of Forest Highway, which provides access to relatively large tracts of the Forest. Forest Highways are roads maintained under another agency's jurisdiction, which on occasion receive reconstruction project funding through the Highway Trust Fund.

There are 885 total miles of National Forest system road under the jurisdiction of the Pisgah National Forest. This mileage is comprised of 345 miles suitable for passenger car use, 215 miles are open to the public all year and 76 miles are seasonally open, and 54 miles are closed to public use. 519 miles of road are only suitable for high clearance vehicular traffic, of which 19 miles are opened to the public all year and 23 miles are seasonally closed with 477 miles closed to public use. There are 64 miles on the system inventory that are closed for periods of time greater than one year, being in "storage" for future use when needed.

The Forest Service catalogs its roads in the official inventory, I-Web, by Maintenance Levels, loosely defined as follows:

- Maintenance Level 5 – Single or Double Lane Paved Roads w/ high degree of user comfort
- Maintenance Level 4 – Moderate User Comfort; primarily double lane aggregate roads with ditches
- Maintenance Level 3 – Lowest level maintained to accommodate passenger car traffic
- Maintenance Level 2 – Maintained primarily only to accommodate use by high clearance vehicles
- Maintenance Level 1 – Closed to all traffic for periods greater than one year.

Table 3 below shows the current break down of the Pisgah National Forest'*s* road system by maintenance level:

Table 3. Pisgah National Forest's road system mileage by Objective Maintenance Level.

| | ML 5 | ML 4 | ML 3 | ML 2 | ML 1 |
|---|---|---|---|---|---|
| Appalachian | 6.9 | 8.3 | 8.1 | 181.6 | 7.4 |
| Grandfather | 19.4 | 8.9 | 92.9 | 171.0 | 9.2 |
| Pisgah | 21.0 | 25.1 | 62.8 | 168.6 | 3.8 |
| Forest Totals | 47.3 | 42.3 | 253.8 | 521.2 | 20.4 |

Private and Coop Roads

Certain roads located on the Pisgah National Forest are needed to provide access to private tracts of land, or by municipalities or large private landowners in cooperation with the Forest. The maintenance responsibility for and jurisdiction of these roads are identified in the official inventory. Generally costs for maintaining these roads are pro-rated to the appropriate benefitting entity, as specified in the enabling agreements.

Unauthorized Roads

At any given time there may be roads found to be in existence on the landscape that are not shown in the inventory or on an official map. These roads are considered to be unauthorized roads, unneeded for use by the Pisgah National Forest. They are subject to decommissioning at any time funding becomes available for that purpose.

Road Maintenance Funding

The Pisgah National Forest maintains its road system primarily with funding provided through the annual Interior and Related Agency's budget, specifically the CMRD line item. The Pisgah National Forest received $423,000 of this funding in fiscal year 2012. Roads that support forest management operations may be maintained with timber sale or stewardship dollars during the life of the operation, but that is not typically a long term solution. Finally, partners and user groups may provide some road maintenance support. In 2012 the Pisgah National Forest received $ 11,300 worth of partner and user support, either in cash or in on-the-ground value, related to the road system.

## Cost of Operating and Maintaining the Pisgah National Forest's Roads and Bridges

Operations Costs

As indicated in the previous section, there is on an annual basis a total of approximately $426,300 available with which to operate and maintain the Pisgah National Forest*'s* road system. Of this, approximately 289,100, or 68% is required in order to cover fixed costs, including management salaries, rent, fleet, travel and training and cost pool contributions. This amount also covers items such as data management, contract preparation and administration and upward reporting. Regardless of the size of the road system being managed this base amount is required. This leaves only about $137,000 to go on the ground for actual maintenance of the road system, and it must cover replacement of deficient bridges as well.

Road Maintenance Costs

The primary components of road maintenance on the Pisgah National Forest include (in addition to inspections) 1) blading and ditching, 2) surfacing (repaving in the case of ML 5), 3) signs and markings, 4) drainage structures, and 5) mowing and brushing. Table 4 displays typical unit costs for these items on the Pisgah National Forest*'s* road system by maintenance level:

Table 4. Typical Unit Costs (annual) for Road Maintenance components on the Pisgah National Forest.

| | ML 5 | ML 4 | ML 3 | ML 2 | ML 1 |
|---|---|---|---|---|---|
| Blading | $ 436 | $ 641 | $ 255 | $ 24 | N/A |
| Ditching | $ 156 | $ 153 | $ 137 | $ 17 | N/A |
| Culvert Cleaning | $ 1,000 | $ 500 | $ 446 | N/A | N/A |
| Culvert Replacement | $ 531 | $ 531 | $ 531 | $ 531 | N/A |
| Gate Repair/Signs | $28 | $ 4 | $ 7 | $20 | $ 25 |
| Gate Replacement | $ 119 | $ 15 | $ 30 | $ 82 | $ 102 |
| Surfacing | $ 8,435 | $ 5,000 | $ 2,408 | $ 55 | N/A |
| Signs and Markings | $ 936 | $ 534 | $ 330 | $ 165 | N/A |
| Minor Damage Repairs | $ 194 | $ 211 | $ 276 | N/A | N/A |
| Mowing and Brushing | $ 500 | $ 500 | $ 451 | $ 333 | $ 22 |
| Totals | $ 12,500 | $ 8,100 | $ 4,900 | $ 1,200 | $ 150 |

Bridge Maintenance and Reconstruction Costs

The Pisgah National Forest has 86 bridges and major culverts. These have to be inspected every other year, at an average cost of about $ 500 per Bridge. At the present time 53 are either known or suspected to be load limited and need to be replaced because they are on roads intended to be left open to traffic. (Load limited bridges will be rated and posted in the interim until funding for replacement can be obtained). Typical bridge replacement costs for the Pisgah National Forest are about $ 6,000 per linear foot for a typical single lane bridge. These costs need to be added to the total road maintenance costs above to get a true picture of the total road and bridge maintenance costs for the next 10 years on the Pisgah National Forest.

Total Cost of Operating and Maintaining the Pisgah National Forest's Roads and Bridges to Standard

Combining the information from the previous sections results in the following table which shows the total annual cost to maintain the Pisgah National Forest's roads and bridges to standard as the system currently exists

Table 5: Cost to Maintain Roads and Bridges

| Item | Number | Unit Cost | Total Cost |
|---|---|---|---|
| Fixed Cost to Operate | 1 LS | $ 289,100 | $ 289,100 |
| Maintenance of Level 1 Roads | 20.4 mi | $ 150 | $ 3,000 |
| Maintenance of Level 2 Roads | 521.2 mi | $ 1,200 | $ 625,500 |
| Maintenance of Level 3 Roads | 253.8 mi | $ 4,900 | $ 1,243,500 |
| Maintenance of Level 4 Roads | 42.3 mi | $ 8,100 | $ 342,500 |
| Maintenance of Level 5 Roads | 47.3 mi | $ 12,500 | $ 591,000 |
| Inspection of ½ of Bridges each Year | 43 ea | $ 500 | $ 21,500 |
| Replacement of Deficient Bridges | 1 LS | $ 223,500 | $ 223,500 |
| Total Annual Cost | | | $ 3,400,000 |

Note: Compare current available budget of 426,300 to the needed amount of $ 3.4 million.

Note: Appendix E in shows the cost of maintaining the "suggested" Optimum Road System" which balances costs and revenue.

## Assessment of Issues, Benefits and Risks

Financial

The primary financial issues relate to the inability to adequately maintain the existing road system with current funding sources. As indicated previously, there is on an annual basis a total of only about $426,300 available with which to operate and maintain the system, whereas the needed funding for the system as currently configured is about $3.4 million. As a result, deferred maintenance continually accrues on the system, but more importantly, it is not possible to maintain Best Management Practices (BMPs) required to adequately protect water quality and associated aquatic life. Meanwhile, roads and bridges are becoming unsafe and are having to be closed, and as a result, the system is failing to meet the needs of both the recreating and travelling public, and to provide for adequate resource access for forest management activities, including prescribed fire and fire suppression.

Environmental and Social

The primary issues in the environmental arena relate to 1) erosion of the roadbed, cut slopes, fill slopes and ditches, with the resulting sediment discharge affecting water quality and associated aquatic resources; 2) in some cases, road density effects on certain wildlife species, such as bear; and 3) the roads serving as a conduit for invasive species. In the social arena, the effects are primarily the demand for adequate access, sometimes offset by the need for providing solitude. Additionally, law enforcement faces challenges due to the high demand. Access is needed by a wide variety of forest users, including hikers, hunters, fishermen and other recreationists, as well as for forest management activities, such as restoration projects and fire suppression. Also, roads require surveillance, as they can easily become sites for crime, illegal dumping and similar activities.

Safety and Function

The primary issues related to safety and function of the Pisgah National Forest*'s* road system include 1) maintenance of a clear and smooth travel way, 2) access in the proximity of the use, 3) steep road grades, 4) functioning of the drainage features, 5) width and stability of the road bed, 6) proper signs and markings, 7) and structurally and functionally sufficient bridges.

Measurement and Rating

Benefits and Risks of the overall system were tabulated and appear in Appendix D. The standard list of questions in the Forest Service Handbook was used as a guide to further assist in identifying the benefits and risks. The degree of risk was rated subjectively as being high, medium or low for the system by appropriate specialists. Then, after considering the entire system, each road was also considered. Those with particular issues, benefits and/or risks different from those of the entire system were identified on the spreadsheet. As related projects become identified at some time in the future, this list may be referenced to inform projects or proposed changes in the Minimum Road System. Risk/Benefit Ratings decision matrix is shown below.

Table 6: Risk/Benefit Matrix

| Risk / Benefit Ratings Decision Matrix | | | | |
|---|---|---|---|---|
| | BENEFITS | | | |
| RISKS | **Scores** | **Low** | **Medium** | **High** |
| | **High** | (HL)<br>Decommission, Mitigate 4th Priority | (HM)<br>Admin Use Only Mitigate 3rd Priority | (HH)<br>Maintain* and Mitigate - Highest Priority |
| | **Medium** | (ML)<br>Close, Decommission Mitigate 7th Priority | (MM)<br>Maintain* Mitigate 5th Priority | (MH)<br>Mitigate and Maintain* - 2nd Priority |
| | **Low** | (LL)<br>Close, Decommission, Admin Use Only | (LM)<br>Maintain* Mitigate 8th Priority | (LH)<br>Maintain* Mitigate 6th Priority |

## Recommendations and Proposed Mitigation Measures

Rationale Used to Arrive at Proposed Minimum Road System

The Chief's March 29, 2012 letter reaffirms that "the Agency expects to maintain an appropriately sized and environmentally sustainable road system that is responsive to ecological, economic, and social concerns. The national forest road system of the future must continue to provide needed access for recreation and resource management, as well as support watershed restoration and resource protection to sustain healthy ecosystems." Budget realities being what they are, roads which are not really needed cannot be supported in the future. Roads that primarily provide access to the public or to a local community need to be considered for transfer of maintenance responsibility, as appropriate. 27.3 Miles were identified that need to be considered in this category. Roads that appear to be unneeded, or which appear to have little benefit yet which are high risk to various environmental or social values were flagged for consideration as decommissioning or long term storage candidates. There are 64 miles in this category. Roads that did not appear to be currently needed for project access during the next decade, and which appear currently to be receiving extremely low use by the public or which appear to not be otherwise needed for management purposes such as fire suppression access were flagged to be considered for storage; there are 22.1 miles in this category. Some roads which are primarily needed only for administrative use, or by hunters and which are currently useable by passenger vehicles were recommended to be considered for conversion to the high clearance. About 29.28 miles were identified that should be considered in this category. Roads which are receiving the highest amount of use, especially by the motoring public, or which access major developed recreation areas, should probably not be downgraded in general.

Inclement weather has a particularly costly impact on native and gravel surfaced roads. Therefore, to the extent possible, roads should be identified for seasonal closure. The TAP recommends that a minimum of 90.32 miles that are currently opened year-round be identified and converted to seasonally closure.

Miles by ML Proposed as Unneeded, by Watershed Condition Class

There are no miles in the Armstrong Creek Watershed that are recommended for decommissioning.

Suggested Conversion of Existing Road System to Minimum Road System

Appendices F lists the existing road system miles by maintenance level, and then proposes changes which respond to the rationale above to comprise the future minimum road system. Although some roads have been suggested to comprise these changes, there are others which have not yet been identified. During the next decade the suggested changes in overall road system makeup should inform projects, and additional individual road change proposals will be identified, with the goal of achieving the proposed minimum road system, and associated financial sustainability as quickly as is practical.

Best Management Practices (BMPs) Applicable to the Pisgah National Forest

When maintaining the forest roads located on the Pisgah National Forest the following Best Management Practices should be adhered to as a minimum:

- National Best Management Practices for Water Quality Management on Forest System Lands

- Applicable State Best Management Practices

- Best Management Practices listed in the current Forest Plan.

- Completed Watershed Action Plans

Appendices

A. Map of Existing Road System
B. Map of Proposed Unneeded Roads
C. Motor Vehicle Use Map(s) MVUMs
D. Tabular Summary of Existing Road System Showing Benefits and Risks
E. Spreadsheets of Existing Road System and Suggested MRS showing Maintenance Costs
F. Comparison of Existing and Suggested Minimum Road Systems (miles by ML)
G. Chief's Letter of Direction
H. Southern Region Expectations
I. $6^{th}$ Level HUCs Watershed Condition Classifications and Priority Watersheds on the Forest
J. Watershed Action Plan

Appendix A – Map of the Existing Road System.  This is an oversized document, therefore only the link is provided:

http://www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb5365160.pdf

Appendix B – Map of the Unneeded Roads.  This is also an oversized document, therefore only the link is provided:

Appendix C – Motor Vehicle Use Maps.  This is also an oversized document, therefore only the link is provided:

http://www.fs.usda.gov/main/nfsnc/maps-pubs

# Appendix D – Existing Road System Benefits and Risks

| **Recreation Benefit** | |
|---|---|
| Information on the amount and types of recreation uses was developed at meetings with district personnel, other public agency representatives, members of the public, and from LRMP management area designation. | **HIGH (2):**<br>Road accesses major developed recreation complex and/or a wide variety of high use dispersed recreation opportunities. |
| | **MEDIUM (1):**<br>Road accesses minor developed recreation area(s) and/or a variety of moderately used dispersed recreation opportunities. |
| | **LOW (0):**<br>Road accesses only minor dispersed recreation opportunities and/or non-motorized use is emphasized (MA 3, MA 4, or other special area MA), or the road's close proximity to Wilderness or other area with special characteristics is producing negative impacts. |

| **Social Benefit** | |
|---|---|
| Information on the amount and types of social uses was developed at meetings with district personnel, members of the public, and Eastern Band of Cherokee. | **HIGH (2):**<br>There are long-standing traditional uses accessed by the road and/or the road is an important through road for local users. |
| | **MEDIUM (1):**<br>There may be some traditional uses accessed by the road or the road offers some convenience to local travelers. |
| | **LOW (0):**<br>There are few if any traditional uses accessed by the road and/or non-motorized use is emphasized (MA3, MA4, or other special area MA). |

| **Resource Management Benefits** | |
|---|---|
| To assign a value for resource management, an analysis was performed to establish how much access a road provides to resource management areas. The amount of access is not only that directly provided by the open road in question, but also from closed system roads that adjoin the open road in question. Roads were rated accordingly: | **HIGH (2):**<br>More than 2.0 miles of road accesses land for resource management |
| | **MEDIUM (1):**<br>More than 0.5 mile and less than 2.0 miles of road accesses land for resource management |
| | **LOW (0):**<br>Less than 0.5 mile of road is accesses land for resource management |

| Fire Management Benefit |
| --- |
| The two primary functions affected within Fire Management are Fuels Management and Fire Suppression. Values are assigned based on the topography, fire history and the relationship of that particular road or area to the area as a whole. The Fire Management Benefit score is the sum of Fuels Management Benefit and Fire Suppression Benefit scores, below, and ranges from 0 to 3. |

| Fuels Management Benefit | |
| --- | --- |
| Fuels Management consists of actively mitigating potential fire behavior by manipulating the fuels amount and arrangement in a given area. | **HIGH (2):**<br>Due to other constraints the roadbed is the only access to areas planned for future treatment, or for accomplishment of treatments currently ongoing in the area. |
| | **MEDIUM (1):**<br>Roadbed is necessary to provide cost effective access for fuels treatment projects, or provides a necessary addition to otherwise occurring human-caused or naturally occurring fuel breaks or barriers in decreasing fuel continuity. |
| | **LOW (0):**<br>Road is not deemed necessary for the current fuels treatments planned or being considered. Fuel arrangement and/or availability are mitigated through other permanent human-caused or natural fuel breaks or barriers. |

| Fire Suppression Benefit | |
| --- | --- |
| Positive need for a road is established by the degree to which the road may allow for more safe and/or efficient fire suppression efforts within the area. Factors to consider include strategic location, navigable terrain, and having vistas of the surrounding environment. | **HIGH (2):**<br>The road provides for a significant firebreak in areas requiring a permanent fuel break such as between forested areas and residential areas, or the road lessens the risk for firefighters and the public by providing necessary access and/or egress to areas having a high fire occurrence risk. |
| | **MEDIUM (1):**<br>The road, in conjunction with time-of-need improvements or other local topographical features provides for a useable fire line or fire break, or provides some degree of usable access to otherwise inaccessible areas. |
| | **LOW (0):**<br>Fire suppression activities are not directed or affected by the presence of the road. Equally the roads may or may not be used for suppression forces or tactics |

| Traffic Volume Benefit | |
|---|---|
| Traffic volume brings both value and risk to a road. On the risk side, high traffic volumes are associated with more risk to public safety and wildlife. On the value side, traffic volume is considered as a surrogate for need. A road with high traffic volume is a road that serves some purpose in the lives of many people. However, even a low volume road may provide a critical need for certain individuals. | **HIGH (2):** |
| | **MEDIUM (1):** |
| | **LOW (0):** |

| Other Unique Benefits |
|---|
| This category considers other unique benefits provided by the road, which are not described by other categories. This score can range from 0 to 2. Most roads should have a zero in this category. |

| Aquatic Biota Vulnerability Risk | |
|---|---|
| Aquatic biota vulnerability is a indicator that factors are associated with this road that mandate extra care be used when considering road-related actions such as maintenance, reconstruction, or changing the level or type of use. In determining the vulnerability rating, the following factors were used: percent of road paralleling stream; number of stream crossings; presence of trout (management indicator species); presence of brook trout. | **HIGH (2):** |
| | **MEDIUM (1):** |
| | **LOW (0):** |

| Risk to Rare Species and Habitats | |
|---|---|
| A GIS analysis was performed to determine roads within 200 feet of any element occurrence of a threatened, endangered, or sensitive species; within 200 feet of a special habitat such as bogs and rock outcrops; or within 200 feet of designated old growth. | **HIGH (2):**<br>More than one element occurrence of a T&E species, or one T&E element occurrence and at least one other factor |
| | **MEDIUM (1):**<br>One element occurrence of a threatened or endangered (T&E) species or one or more other factors are present. |
| | **LOW (0):**<br>None of the above factors occurs within 200 feet of the road |

| Risk to Wildlife | |
|---|---|
| The factors used to assign wildlife-associated risks to roads included: extremely excessive open road density in a management area "4;" poaching is known to have occurred; proximity to bear sanctuary; and high traffic volume. | **HIGH (2):**<br>More than two of the above risk factors are present. |
| | **MEDIUM (1):**<br>One or two of the above risk factors is present. |
| | **LOW (0):**<br>None of the above risk factors is present. |

| Wildfire Suppression Risk | |
|---|---|
| The risks are associated with providing a road that is an apparent tool, which upon further inspection increases the overall hazards of the suppression efforts. A road would be valued negatively overall if it seemingly provides access only to effectively draw a crew into an entrapment | **HIGH (2):**<br>The roadbed is not maintained to support larger, heavier equipment. The road dead-ends with limited or no options to turn equipment around. Limited sight distance. Switchbacks are sharp, steep or routinely rutted/rained out. The roadbed follows along or crosses into the bottom of a drainage. The road ownership patterns make it hard to predict obstacles or hazards |

| | |
|---|---|
| situation. The current use of crews from out of the local area and the availability of aircraft for both reconnaissance and suppression were factors in determining the risk rating of some of the roads. | **MEDIUM (1):**<br>The road doesn't enhance the safety of firefighters or the public. The roadbed and or the surrounding fuels are not situated or maintained to provide a safety zone more effectively than naturally occurring openings in the area. The road has limited access/egress opportunities. |
| | **LOW (0):**<br>The road and turnouts are adequate for controlled moderate to heavy traffic and the roadbed including switchbacks are maintained to provide safe passage of larger or heavier fire suppression equipment. Sight distances are adequate. The road has multiple access points. |

| **Heritage Resources Risk** | |
|---|---|
| A GIS analysis was performed to determine roads within 200 feet of any known archeological sites or areas. In addition, the Forest archeologist and Eastern Band of Cherokee Indians provided additional information | **HIGH (2):**<br>Four or more sites per mile of road |
| | **MEDIUM (1):**<br>Two or three sites per mile of road |
| | **LOW (0):**<br>Less than two known sites per mile of road |

| **Risk to Public Safety** | |
|---|---|
| Public safety is a critical factor in managing the transportation system. The following factors were considered in assigning a public safety risk to each road: presence of pedestrian traffic; amount of vehicular traffic; amount of year road is open; condition of road; excessive speed identified as issue; other identified law enforcement issue; other identified safety issue. | **VERY HIGH (3):** |
| | **HIGH (2):** |
| | **MEDIUM (1):** |
| | **LOW (0):** |

| **Maintenance Cost Risk** | |
|---|---|
| The shortfall in maintenance dollars is one reason the Roads Analysis Process regulations were passed. Because funding is not adequate for identified needs, those roads with higher total road maintenance needs, including annual and deferred, are a higher risk for health and safety and resource damage. A risk factor is assigned to each road based on the total cost of maintenance per mile. Table V-12 displays a summary of the results. | **VERY HIGH (3):**<br>> $50,000 per mile |
| | **HIGH (2):**<br>$25,000 - $49,999 per mile |
| | **MEDIUM (1):**<br>$7,500 - $24,999 per mile |
| | **LOW (0):**<br><$7,500 per mile |

# Appendix E – Spreadsheets of Existing Road System and Suggested MRS showing Maintenance Costs

Annual Cost of Maintaining the Pisgah National Forest's Roads and Bridges*

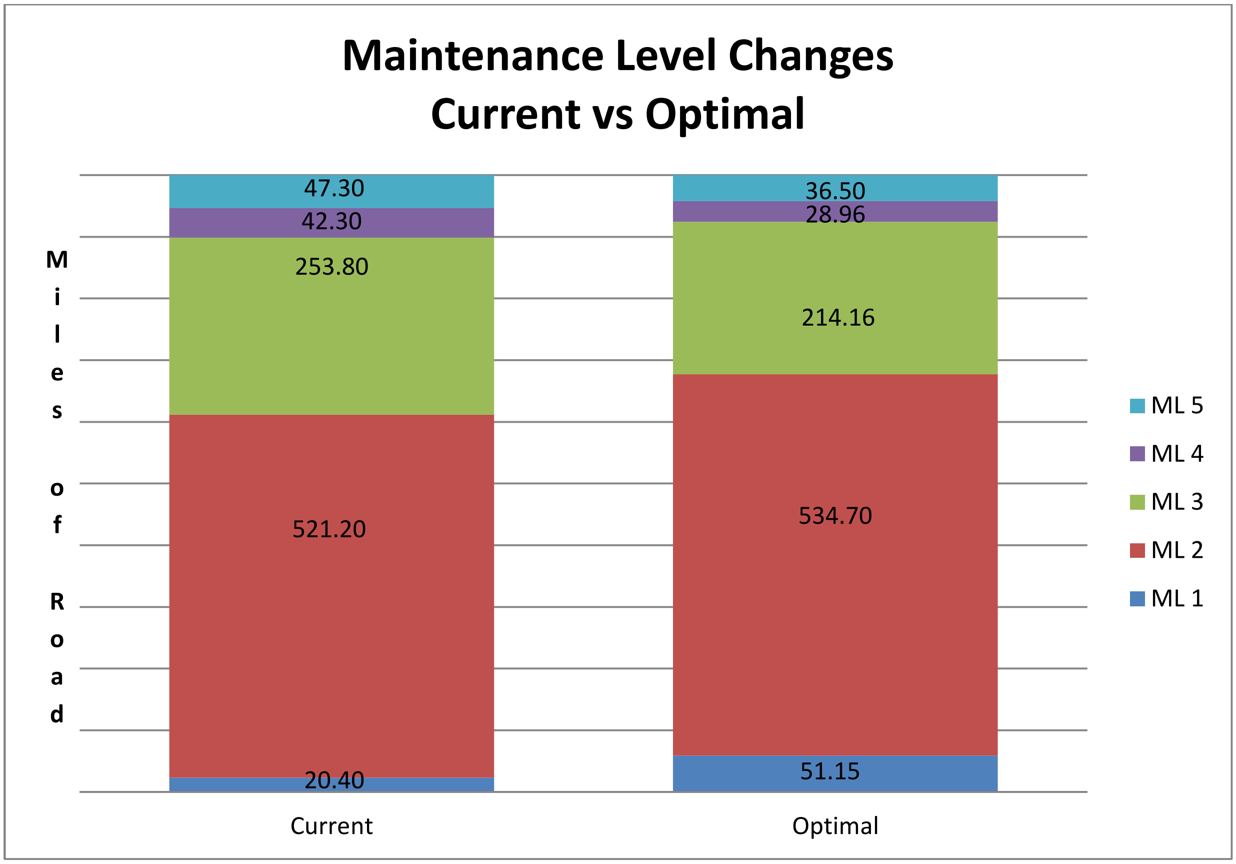
| Item/Objective Maintenance Level | Number/Miles by Objective Maintenance Level | Unit Maintenance Cost | Total Annual Road Maintenance Cost |
|---|---|---|---|
| Fixed Cost to Operate | 1 LS | $ 289,100 | $ 289,100 |
| Maintenance of Level 1 Roads | 20.4 mi | $ 150 | $ 3,000 |
| Maintenance of Level 2 Roads | 521.2 mi | $ 1,200 | $ 625,500 |
| Maintenance of Level 3 Roads | 253.8 mi | $ 4,900 | $ 1,243,500 |
| Maintenance of Level 4 Roads | 42.3 mi | $ 8,100 | $ 342,500 |
| Maintenance of Level 5 Roads | 47.3 mi | $ 12,500 | $ 591,000 |
| Inspection of ½ of Bridges each Year | 43 ea | $ 500 | $ 21,500 |
| Replacement of Deficient Bridges | 1 LS | $ 223,500 | $ 223,500 |
| Total Annual Cost | | | $ 3,400,000 |

*Bridge replacement costs included as annualized amount

Annual Cost of Maintaining the Pisgah National Forest's Roads and Bridges suggested future road system

| Item/Objective Maintenance Level | Number/Miles by Objective Maintenance Level | Unit Maintenance Cost | Total Annual Road Maintenance Cost |
|---|---|---|---|
| Fixed Cost to Operate | 1 LS | $ 289,100 | $ 289,100 |
| Maintenance of Level 1 Roads | 20.4 mi | $ 150 | $ 3,000 |
| Maintenance of Level 2 Roads | 521.2 mi | $ 1,200 | $ 625,500 |
| Maintenance of Level 3 Roads | 253.8 mi | $ 4,900 | $ 1,243,500 |
| Maintenance of Level 4 Roads | 42.3 mi | $ 8,100 | $ 342,500 |
| Maintenance of Level 5 Roads | 26 mi | $ 12,500 | $ 591,000 |
| Inspection of ½ of Bridges each Year | 43 ea | $ 500 | $ 21,500 |
| Replacement of Deficient Bridges | 1 LS | $ 223,500 | $ 223,500 |
| Total Annual Cost | | | $ 3,400,000 |

Appendix F – Comparison of Existing and Suggested Optimal Road System Miles by Maintenance Level




| Maintenance Level | Current | Optimal |
|---|---|---|
| Maintenance Level 1 | 20.40 | 51.15 |
| Maintenance Level 2 | 521.20 | 534.70 |
| Maintenance Level 3 | 253.80 | 214.16 |
| Maintenance Level 4 | 42.30 | 28.96 |
| Maintenance Level 5 | 47.30 | 36.50 |
| | 885.00 | 865.47 |

# Appendix G – Chief's Letter of Direction

**File Code:** 2300/2500/7700 **Date:** March 29, 2012
**Route To:**

**Subject:** Travel Management, Implementation of 36 CFR, Part 202, Subpart A (36 CFR 212.5(b))

**To:** Regional Foresters, Station Directors, Area Director, IITF Director, Deputy Chiefs and WO Directors

This letter is to reaffirm agency commitment to completing a travel analysis report for Subpart A of the travel management rule by 2015 and update and clarify Agency guidance. This letter replaces the November 10, 2010, letter on the same topic.

The Agency expects to maintain an appropriately sized and environmentally sustainable road system that is responsive to ecological, economic, and social concerns. The national forest road system of the future must continue to provide needed access for recreation and resource management, as well as support watershed restoration and resource protection to sustain healthy ecosystems.

Forest Service regulations at 36 CFR 212.5(b)(1) require the Forest Service to identify the minimum road system needed for safe and efficient travel and for administration, utilization, and protection of National Forest System (NFS) lands. In determining the minimum road system, the responsible official must incorporate a science-based roads analysis at the appropriate scale. Forest Service regulations at 36 CFR 212.5(b)(2) require the Forest Service to identify NFS roads that are no longer needed to meet forest resource management objectives.

**Process**

Travel analysis requires a process that is dynamic, interdisciplinary, and integrated with all resource areas. With this letter, I am directing the use of the travel analysis process (TAP) described in Forest Service Manual 7712 and Forest Service Handbook (FSH) 7709.55, Chapter 20. The TAP is a science-based process that will inform future travel management decisions. Travel analysis serves as the basis for developing proposed actions, but does not result in decisions. Therefore, travel analysis does not trigger the National Environmental Policy Act (NEPA). The completion of the TAP is an important first step towards the development of the future minimum road system (MRS). All NFS roads, maintenance levels 1-5, must be included in the analysis.

For units that have previously conducted their travel or roads analysis process (RAP), the appropriate line officer should review the prior report to assess the adequacy and the relevance of their analysis as it complies with Subpart A. This analysis will help determine the appropriate scope and scale for any new analysis and can build on previous work. A RAP completed in accordance with publication FS-643, "Roads Analysis: Informing Decisions about Managing the National Forest Transportation System," will also satisfy the roads analysis requirement of Subpart A.

Results from the TAP must be documented in a **travel analysis report**, which shall include:

- A map displaying the roads that can be used to inform the proposed action for identifying the MRS and unneeded roads.
- Information about the analysis as it relates to the criteria found in 36 CFR 212.5(b)(1).

Units should seek to integrate the steps contained in the Watershed Condition Framework (WCF) with the six TAP steps contained in FSH 7709.55, Chapter 20, to eliminate redundancy and ensure an iterative and adaptive approach for both processes. We expect the WCF process and the TAP will complement each other. The intent is for each process to inform the other so that they can be integrated and updated with new information or where conditions change. The travel analysis report described above must be completed by the end of FY 2015.

The next step in identification of the MRS is to use the travel analysis report to develop proposed actions to identify the MRS. These proposed actions generally should be developed at the scale of a 6$^{th}$ code sub watershed or larger. Proposed actions and alternatives are subject to environmental analysis under NEPA. Travel analysis should be used to inform the environmental analysis.

The administrative unit must analyze the proposed action and alternatives in terms of whether, per 36 CFR 212.5(b)(1), the resulting road system is needed to:

- Meet resource and other management objectives adopted in the relevant land and resource management plan;
- Meet applicable statutory and regulatory requirements;
- Reflect long-term funding expectations;
- Ensure that the identified system minimizes adverse environmental impacts associated with road construction, reconstruction, decommissioning, and maintenance.

The resulting decision identifies the MRS and unneeded roads for each sub watershed or larger scale. The NEPA analysis for each sub watershed must consider adjacent sub watersheds for connected actions and cumulative effects. The MRS for the administrative unit is complete when the MRS for each sub watershed has been identified, thus satisfying Subpart A. To the extent that the sub watershed NEPA analysis covers specific road decisions, no further NEPA analysis will be needed. To the extent that further smaller-scale, project-specific decisions are needed, more NEPA analysis may be required.

A flowchart displaying the process for identification of the MRS is enclosed with this letter.

**Timing**

The travel analysis report **must be completed by the end of FY 2015**. Beyond FY 2015, no Capital Improvement and Maintenance (CMCM) funds may be expended on NFS roads (maintenance levels 1-5) that have not been included in a TAP or RAP.

**Leadership**

The Washington Office lead for Subpart A is Anne Zimmermann, Director of Watershed, Fish, Wildlife, Air and Rare Plants. Working with her on the Washington Office Steering Team are Jim Bedwell, Director of Recreation, Heritage, and Volunteer Resources, and Emilee Blount, Director of Engineering. I expect the Regions to continue with the similar leadership structures which have been established.

Your leadership and commitment to this component of the travel management rule is important. Together, we will move towards an ecologic, economic, and socially sustainable and responsible national road system of the future.

*/s/ James M. Pena (for):*
LESLIE A. C. WELDON

Deputy Chief, National Forest System

# Appendix H: Southern Region Expectations

**Southern Region Expectations**
**Revised to align with 2012 Chief's Letter**

A. Background. During the period 2005 - 2010 the National Forests of the Southern Region successfully completed Sub-Part "B" (Designation of Roads, Trails and Areas for Motor Vehicle Use) Travel Analysis. The result was a set of Motor Vehicle Use Maps (MVUMs) which prescribe the Forest Service roads that allow traffic; and in doing so it also prohibited cross-country travel by off-highway vehicles (OHVs). Forests are now beginning work on Sub-Part "A" (Administration of the Forest Transportation System) Travel Analysis to identify the minimum road system needed for safe and efficient travel and for the protection, management and use of NFS lands; and also to identify roads no longer needed to meet forest resource management objectives.

TAP analysis identifies risks and benefits of individual roads in the system, but especially cumulative effects and affordability of the entire system. Consideration is given to the access needed to support existing Forest Plans, and for informing future Forest Plans and resulting projects. TAP is intended to identify opportunities to assist managers in addressing the unique ecological, economic and social conditions on the national forests and grasslands.
B. Agency Direction. Sub-Part "A" Travel Analysis is required by the 2005 Travel Management Rule (36 CFR 212.5). Forest Service Manual 7712 and Forest Service Handbook 7709.55 Chapter 20 provides specific direction, including the requirement to use a six step interdisciplinary, science-based process to ensure that future decisions are based on an adequate consideration of environmental, social and economic impacts of roads. A letter from the Chief of the Forest Service dated March 29, 2012 was issued to replace a November 10, 2010 letter previously issued on the same topic. It reaffirms agency commitment to completing travel analysis reports for Subpart A of the travel management rule by 2015, and also provides additional national direction related to this work, addressing process, timing and leadership expectations. The letter requires documentation of the analysis by a travel analysis report, which includes a map displaying the existing road system and possible unneeded roads. It is intended to inform future proposed actions related to identifying the minimum road system. The TAP process is designed to work in conjunction with other frameworks and processes, the results of which collectively inform and frame future decisions executed under NEPA. These other analyses and procedures include Watershed Analysis Framework and mapping; Recreational Framework planning and analyses; and forest-wide planning under the new Planning Rule. This document (Southern Region Expectations) supplements the national direction for Sub-Part "A" TAPs developed for the Southern Region.

C. Geographic Scale. Like smaller scale road analyses (RAPS) that have been underway at the project level, TAPs consider economic, environmental and social effects of roads. Analysis at the smaller project scale, however, does not adequately address cumulative effects and affordability. The Chief's letter requires that proposed NEPA actions be informed by work at the 6th order HUC watershed as a minimum. Southern Region Expectations are for a Unit TAP at the District level or equivalent; and since budgets are generally allocated to the Forest level, District analyses are not considered complete until all other Districts on the same Forest are also complete and have been integrated to create a Forest Scale TAP. As projects which involve travel (road) decisions are subsequently proposed on a unit, additional project level analysis will be required in advance of associated NEPA decisions only if the proposal varies substantially from the Unit Scale TAP covered by it. The purpose would be to show any additional impact on cumulative effects and affordability.

D. Process, Review and Approval. Forests Interdisciplinary Teams (IDTs) are expected to conduct analyses, with guidance and review by the Regional Office TAP Review Team (members listed below). Standard boilerplate, spreadsheets and Executive Summary format will be developed by the Review team for incorporation into the TAP reports. Final review will be by the Forest Supervisor, indicating that the analyses comply with national and regional direction. Upon completion of the last District TAP on a Forest, the Forest Supervisor needs to submit a forest-wide Executive Summary and verify that the cumulative results meet the expectations defined in this guidance.

The Regional TAP Review Team consists of Team Leader Paul Morgan (Engineering), Emanuel Hudson (Biological and Physical Resources), Mary Hughes Frye (Recreation), Paul Arndt (Planning) and various other ad hoc members as needed. They will submit their review comments to the TAP Steering Team prior to officially conveying them to the Forest. The Steering Team will be responsible for overall direction and oversight of the process. This team consists of Randy Warbington, TAP Steering Team Lead and Director of Engineering, Dave Schmid, Director of Biological and Physical Resources, Chris Liggett, Director of Planning, and Ann Christensen, Director of Recreation as well as George Bain, Forest Supervisor on the Chattahoochee Oconee NF's and Steve Bekkerus, Regional Legislative Affairs Specialist.
E. Information Systems. Analysis will be based upon field-verified spatial data (GIS, or Geographic Information System road and trail layers), and official tabular data (from I-Web, the corporate Forest Service data base) as applicable. ARC Map products will be included as a part of all completed Unit Scale TAPs, and will be provided to the Regional Office TAP review team as a part of the final TAP report.

F. **Access.** As prescribed by 16USC532 the Forest Roads and Trails Act TAPs should identify an adequate system of roads and trails to provide for intensive use, protection, development, and management of National Forest System lands. As such, they should address user safety and environmental impacts, and provide for an optimum balance of access needs and cost. Roads, trails and bridges that are unsafe and where unacceptable risks cannot be eliminated or mitigated due to a lack of funding should be identified for closure or possible decommissioning. Unneeded, temporary and unauthorized routes should be identified for possible decommissioning. TAPs should support current Forest Plan direction and anticipate future Forest Plan analysis needs, as well as Recreational Framework planning and analyses. As unit scale TAPs are completed, associated MVUMs must be reviewed. After appropriate NEPA decisions are made to implement TAP recommendations, future MVUM revisions need to be revised to assure that they are in agreement with those decisions.

G. **Environmental.** One major analysis component of the TAPs is impact of the road system on water quality. In those cases where high road densities on National Forest lands are a major factor in causing watersheds to be at risk or impaired, some roads should be identified for decommissioning in order to reduce the impacts and change the classification. Also, it should be recognized that some existing roads are poorly located and should be eliminated, while some new roads might be needed to replace them and provide essentially equivalent access in better locations, generally farther away from live streams or wetlands. The Watershed Condition Framework should inform each unit's travel analysis. An overriding objective for all roads should be compliance with provisions cited in National Best Management Practices for Water Quality Management on National Forest System Lands, April 2012. While a reduction in maintenance levels may be a desired option for cost reduction, it is not an appropriate strategy when it results in more environmental impacts. Similarly, changes in recreational use should be considered, especially for roads that cannot be maintained to standard and which may begin to attract challenge-oriented four-wheelers that create even further impacts on the environment and on the road.

H. **Financial.** Units should consider all expected sources of funding available to maintain the road system to appropriate standards (based upon 3 year history and current trends), and include all costs that are required to comply with applicable Best Management Practices (BMPs) for their maintenance. Include associated bridge maintenance as well, and replacement costs for those routes which include bridges that are deficient or expected to need major work in the next ten year period. Identify and account for fixed costs (program management, fleet, etc.) when analyzing financial feasibility. Ultimately units must balance the costs of maintaining the identified system such that the recommendation will not result in accrual of deferred maintenance on roads and bridges once the TAP is implemented (i.e. there should be a zero balance between anticipated maintenance revenue and anticipated maintenance cost on an annual basis).

The focus of this analysis should not be primarily on disinvestment, i.e. just reducing passenger car roads to high clearance roads in order to meet funding constraints. Roads receiving minimal maintenance have the high likelihood, at least those roads located relatively low in the watershed, of creating additional siltation impacts. They can also have unintended consequences for recreation management. Therefore a better strategy might be to identify roads not required for current operations but which might be needed at some time in the future for seasonal or intermittent closure, or "storage". Other strategies might include scheduling maintenance over a two to three year cycle on less used roads, adding seasonal restrictions, identifying roads to transfer to state or local jurisdiction, and identifying unneeded roads for possible decommissioning. Total mileage of high clearance roads should not generally increase over the amount in the current system unless it is determined that there has been substantial maintenance level "creep" over the years and therefore a substantial increase in high clearance roads is warranted. However it is expected that the number of roads identified to be placed in storage will generally increase from the current level. Finally it should be noted that similar to the road system, the trail system is also over-committed to be managed within its maintenance budget. Therefore, unless maintenance funding is verified to be available over the long-term, it is not acceptable to identify roads for conversion to trails; the more appropriate options would be storage or decommissioning, depending upon future need.

I. Public Involvement and NEPA (National Environmental Protection Act) Requirements. Unit scale TAPs are not NEPA decisions; they are analyses intended to inform future projects regarding affordability and cumulative effects. These projects, depending upon the specific impacts, will generally require NEPA decisions prior to implementation. The public will need to be provided opportunities for comment on TAP recommendations near to the time that those actual projects are being proposed. This would be expected to include a broad spectrum of participation by citizens, other agencies, and tribal governments as appropriate.

J. Products. All final products to be posted on an internal website or on the "O" drive available for access by other Forests and the Regional Office. The final product should consist of the following items:

1) A Travel Analysis Report summarizing the process the results of all analyses conducted.

2) A map showing the entire Road System, ML 1-5, and delineating potential unneeded roads.

3) A list of roads that are proposed for transfer to another jurisdiction and whether acceptance by that jurisdiction is likely within the next three years.

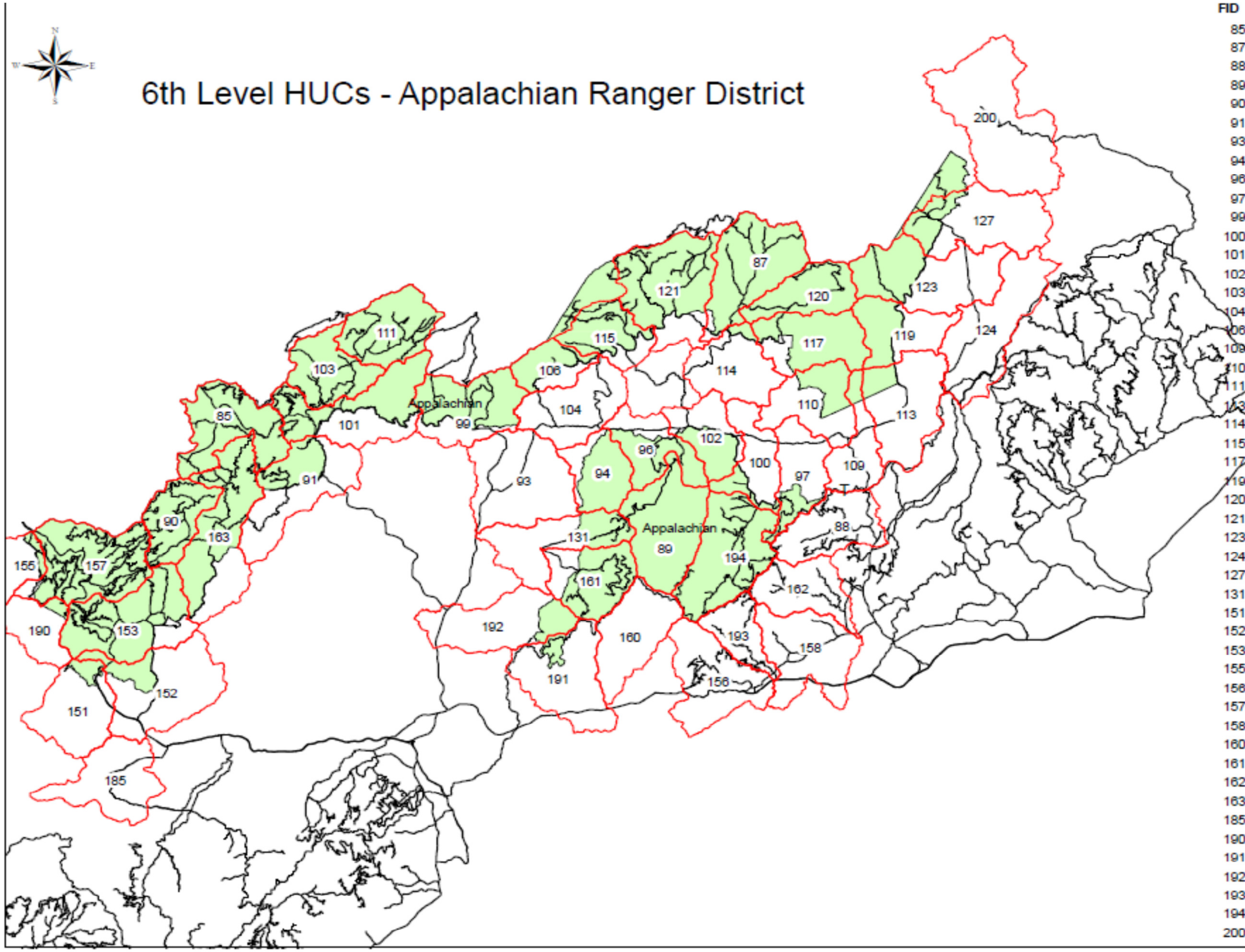
4) A tabular summary of issues, benefits and risks for each road in the system. (Although not included in this write-up an example format is available and will be provided to each unit as they begin work on their TAP.)

5) A spreadsheet identifying available maintenance funding and expected costs for applying affordable operational maintenance levels and associated BMPs (best management practices) to the road system to result in a financial strategy that balances funding and costs such that no deferred maintenance will accrue if fully implemented.

6) Signature sheets with dates, indicating preparation and review officials, and Review by the Forest Supervisor.

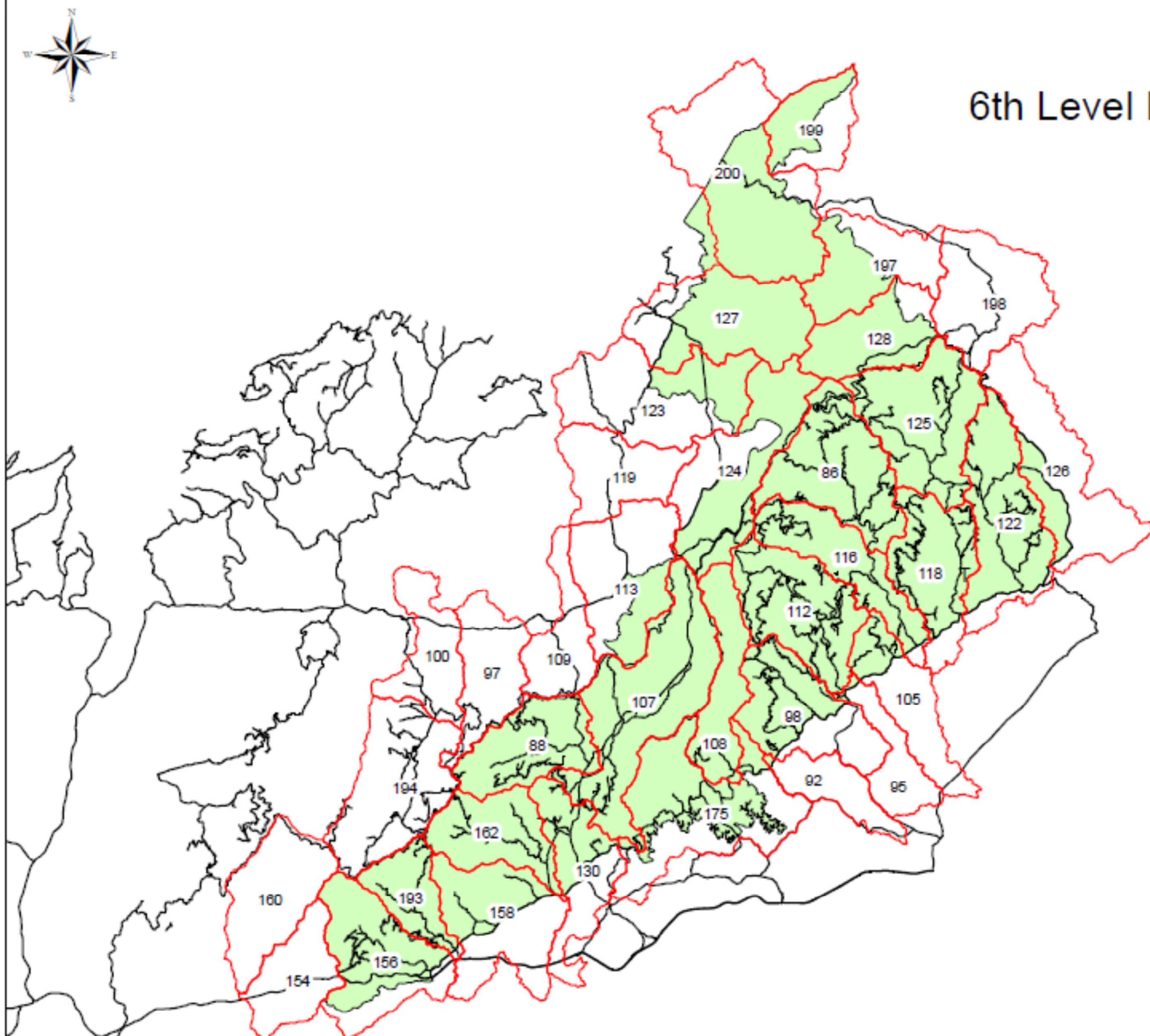
K. Schedule and Completion Date.
The chief's letter directs that all units be covered by a TAP by the end of FY 2015. The proposed schedule is as follows:
Croatan NF, NFs in North Carolina – FY11
Pisgah NF in NC – FY12
Nantahala NF in NC – FY13
Uwharrie RD, NFs in NC – FY14

Appendix I: 6th Level HUCs Watershed Condition Classification and Priority Watersheds on the Forest

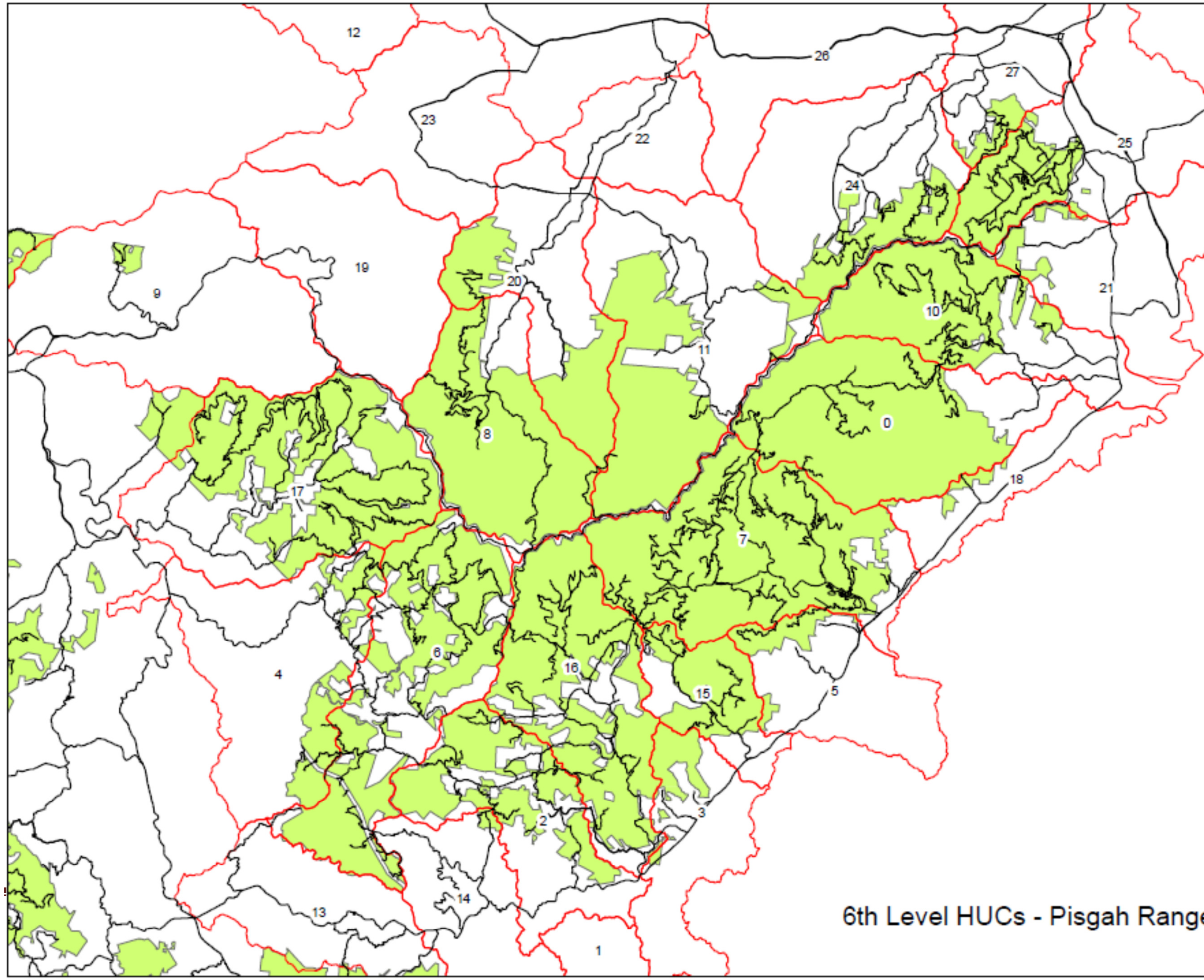



| FID | HUC_12_13 | HUC_12_NAM |
|---|---|---|
| 85 | 060101051203 | Shut-in Creek-French Broad River |
| 87 | 060101080603 | Big Rock Creek |
| 88 | 030501010201 | Armstrong Creek |
| 89 | 060101080301 | Headw aters Cane River |
| 90 | 060101051201 | Meadow Fork |
| 91 | 060101051103 | Big Pine Creek-French Broad River |
| 93 | 060101050802 | Little Ivy Creek |
| 94 | 060101080302 | Price Creek |
| 96 | 060101080303 | Upper Cane River |
| 97 | 060101080105 | Big Crabtree Creek |
| 99 | 060101051001 | Upper Big Laurel Creek |
| 100 | 060101080203 | Low er South Toe River |
| 101 | 060101051004 | Low er Big Laurel Creek |
| 102 | 060101080202 | Little Crabtree Creek |
| 103 | 060101051003 | Low er Shelton Laurel Creek |
| 104 | 060101080305 | Middle Cane River |
| 106 | 060101080304 | Bald Mountain Creek |
| 109 | 060101080104 | Grassy Creek-North Toe River |
| 110 | 060101080106 | Bear Creek-North Toe River |
| 111 | 060101051002 | Upper Shelton Laurel Creek |
| 113 | 060101080103 | Threemile Creek-North Toe River |
| 114 | 060101080205 | Pigpen Creek-North Toe River |
| 115 | 060101080306 | Low er Cane River |
| 117 | 060101080204 | Cane Creek |
| 119 | 060101080102 | Plumtree Creek-North Toe River |
| 120 | 060101080602 | Little Rock Creek |
| 121 | 060101080604 | Hollow Poplar Creek-Nolichucky River |
| 123 | 060101080101 | Headw aters North Toe River |
| 124 | 030501010301 | Upper Linville River |
| 127 | 060101030201 | Upper Elk River |
| 131 | 060101050803 | Upper Ivy Creek |
| 151 | 060101060204 | Low er Johnathans Creek |
| 152 | 060101060205 | Crabtree Creek-Pigeon River |
| 153 | 060101060303 | Walters Lake-Pigeon River |
| 155 | 060101060304 | Big Creek |
| 156 | 030501010102 | Headw aters Cataw ba River |
| 157 | 060101060305 | Cold Springs Creek-Pigeon River |
| 158 | 030501010105 | Mackey Creek-Cataw ba River |
| 160 | 060101050601 | North Fork Sw annanoa River |
| 161 | 060101050801 | Dillingham Creek |
| 162 | 030501010104 | Buck Creek |
| 163 | 060101051202 | Spring Creek |
| 185 | 060101060202 | Low er Richland Creek |
| 190 | 060101060302 | Low er Cataloochee Creek |
| 191 | 060101050603 | Middle Sw annanoa River |
| 192 | 060101050903 | Reems Creek |
| 193 | 030501010101 | Curtis Creek |
| 194 | 060101080201 | Upper South Toe River |
| 200 | 060101030305 | Beech Creek-Watauga River |

# 6th Level HUCs - Grandfather Ranger District




| FID | HUC_12 | HU_12_Name |
|---|---|---|
| 86 | 030501010502 | Upper Wilson Creek |
| 88 | 030501010201 | Armstrong Creek |
| 92 | 030501010605 | Canoe Creek |
| 95 | 030501010403 | Lower Warrior Fork |
| 97 | 060101080105 | Big Crabtree Creek |
| 98 | 030501010402 | Irish Creek |
| 100 | 060101080203 | Lower South Toe River |
| 105 | 030501010506 | Lower Johns River |
| 107 | 030501010202 | North Fork Catawba River |
| 108 | 030501010302 | Lower Linville River |
| 109 | 060101080104 | Grassy Creek-North Toe River |
| 112 | 030501010401 | Upper Warrior Fork |
| 113 | 060101080103 | Threemile Creek-North Toe River |
| 116 | 030501010504 | Lower Wilson Creek |
| 118 | 030501010505 | Middle Johns River |
| 119 | 060101080102 | Plumtree Creek-North Toe River |
| 122 | 030501010503 | Mulberry Creek |
| 123 | 060101080101 | Headwaters North Toe River |
| 124 | 030501010301 | Upper Linville River |
| 125 | 030501010501 | Upper Johns River |
| 126 | 030401010102 | Headwaters Yadkin River |
| 127 | 060101030201 | Upper Elk River |
| 128 | 060101030301 | Headwaters Watauga River |
| 130 | 030501010106 | Toms Creek-Catawba River |
| 154 | 060101050602 | Upper Swannanoa River |
| 156 | 030501010102 | Headwaters Catawba River |
| 158 | 030501010105 | Mackey Creek-Catawba River |
| 160 | 060101050601 | North Fork Swannanoa River |
| 162 | 030501010104 | Buck Creek |
| 175 | 030501010303 | Lake James-Catawba River |
| 193 | 030501010101 | Curtis Creek |
| 194 | 060101080201 | Upper South Toe River |
| 197 | 060101030303 | Dutch Creek-Watauga River |
| 198 | 050500010201 | Headwaters South Fork New River |
| 199 | 060101030304 | Beaverdam Creek |
| 200 | 060101030305 | Beech Creek-Watauga River |




| FID | HUC_12 | HU_12_Name |
|---|---|---|
| 0 | 060101050402 | South Fork Mills River |
| 1 | 030601010102 | Toxaway River-Lake Jocassee |
| 2 | 060101050102 | West Fork French Broad River |
| 3 | 060101050105 | Cherryfield Creek-French Broad River |
| 4 | 060102030104 | Cedar Cliff Lake-Tuckasegee River |
| 5 | 060101050203 | Williamson Creek-French Broad River |
| 6 | 060102030101 | Wolf Creek-Tuckasegee River |
| 7 | 060101050202 | Davidson River |
| 8 | 060101060101 | Lake Logan-West Fork Pigeon River |
| 9 | 060102030302 | Headwaters Scott Creek |
| 10 | 060101050403 | Mills River |
| 11 | 060101060103 | East Fork Pigeon River |
| 12 | 060101060204 | Lower Johnathans Creek |
| 13 | 030601010103 | Horsepasture River |
| 14 | 030601010101 | Lake Toxaway-Headwaters Toxaway |
| 15 | 060101050104 | Catheys Creek |
| 16 | 060101050101 | North Fork French Broad River |
| 17 | 060102030105 | Caney Fork |
| 18 | 060101050401 | Boylston Creek |
| 19 | 060101060201 | Upper Richland Creek |
| 20 | 060101060102 | Little East Fork Pigeon River-West Fork |
| 21 | 060101050704 | Avery Creek-French Broad River |
| 22 | 060101060104 | Garden Creek-Pigeon River |
| 23 | 060101060202 | Lower Richland Creek |
| 24 | 060101050501 | South Hominy Creek |
| 25 | 060101050705 | Bent Creek-French Broad River |
| 26 | 060101050502 | Upper Hominy Creek |

## 6th Level HUCs - Pisgah Ranger District

# Appendix J:  Watershed Action Plan

USDA Forest Service Watershed Condition Framework

FY2011 TRANSITION WATERSHED RESTORATION ACTION PLAN

National Forests in North Carolina

1. Summary

**a.** Watershed Name and HUC: Armstrong Creek (030501010201)
**b.** General Location:  The Armstrong Creek Watershed is located on the Grandfather Ranger District, Pisgah National Forest of McDowell County, North Carolina.
**c.** Total Watershed Area: 18,303 acres;       NFS area within watershed: 46%.
**d.** Watershed Characterization:

- General Physiography: The Armstrong Creek Watershed is within the Blue Ridge Mountain Physiographic Province draining in an easterly direction on the Atlantic Slope in the Catawba River Basin.  The topography of the area is mountainous with strongly sloping to very steep uplands and narrow floodplains along the streams in FS ownership.  Soils are dominated by the Chestnut-Ashe complex (CaF) and Edneyville-Chestnut complex (EcF), both steep with slopes ranging from 25 to 80 percent and stony.  These soil types both have “severe” erosion concerns for management because of steep slopes.  Average annual precipitation can be as high as 74.5 inches (data from nearby Mt. Mitchell), but more likely slightly lower due to a lower elevation.  Stream channels are predominantly stable with an abundance of large rock substrate and banks.
- Land Use:  The predominant land use in the Armstrong Creek Watershed is forested with low-volume roads accessing only about half of the area.  Forest Plan management areas include MA 4C (emphasis – scenery) and 4D (emphasis – wildlife habitat) in the northwest, MA 3B (emphasis – timber supply) and small areas of 2C (emphasis – timber & scenery) in the northeast, and MA 5 (emphasis – backcountry area) in the southern portion of the watershed.  Private lands in the watershed are managed for forestry in the steeper mountains and agriculture, grazing, industry, and homes in the flatter areas.
- General Overview of Concerns:  The Armstrong Creek Watershed ranked in a condition class of “Fair” or “Functioning at Risk”.  Several indicators ranked “Poor” or “Not Properly Functioning” including; Aquatic Habitat – Large Woody Debris (LWD), Aquatic Biota – Native Species, Roads and Trails- Open Road Density, - Road Maintenance, - Proximity to Water, and  - Mass Wasting, Soil Contamination, and Fire Condition Class.
- Important Ecological Values:  These include State designated High Quality Waters, aquatic habitat for native species, terrestrial wildlife species, and Hudsonia montana on southern ridge tops.
- Current Condition Class:  Fair (1.8)   Target Condition Class: Good

**e.** **Key Watershed Issues**

1) Attributes/Indicators  within FS control to affect

| ATTRIBUTES /INDICATOR | REASON FOR RATING |
|---|---|

| | |
|---|---|
| 3.1 Aquatic Habitat Fragmentation | Although rated as Properly Functioning (score of 1.33), the culvert on FSR 469 of Caney Creek is a barrier to aquatic passage. |
| 3.2 Aquatic - Large Woody Debris | Rated as Not Properly Functioning (score of 3.00) due to the lack of LWD incorporated into the stream ecosystem. |
| 5.1 Riparian/Wetland Vegetation Condition | Rated as Properly Functioning (score of 1.00), however with the high hemlock mortality in the streamside areas and the overabundance of a single species (Rhododendron) there is a need to restore these areas to a more diverse vegetative composition. |
| 6.2 Road/Trail Maintenance | Rated as Not Properly Functioning (score of 3.00), the proposed trail work would reduce the need for maintenance on the trail system. |
| 6.3 Road/Trail Proximity to Water | Rated as Not Properly Functioning (score of 3.00), the proposed trail work would reduce the length of trail system in close proximity to the stream course. |
| 7.1 Soil Productivity | Although rated as Properly Functioning (score of 1.00), little is known about soil productivity in the watershed. The proposed inventory would affirm the need for restoration of base cation losses. |
| 8.1 Fire Condition Class | Rated as Not Properly Functioning (score of 3.00), prescribed fire is needed on the landscape to restore fire dependent vegetative communities, and one federally listed fire dependent species, Hudsonia montana. |
| 9.1 Loss Forest Cover | Although rated as Properly Functioning (score of 1.00), Forest Cover would be restored in stream side areas where hemlock mortality is high and the dominance of a single shrub species (Rhododendron) would not allow for a more diverse vegetative composition and may inhibit tree regeneration. |
| 11.1 Terrestrial Invasives | Although rated as Properly Functioning (score of 1.00), there is a need to treat non-native and invasive plant species along the FSR 469 road network prior to vegetation management. |
| 12.1 Forest Health – Insects & Disease | Although rated as Properly Functioning (score of 1.00), there is a need to restore American Chestnut and restore Rich Cove Forest diversity. |

2) Attributes/Indicators that require other parties to address

| **ATTRIBUTES /INDICATOR** | **REASON FOR RATING** |
|---|---|
| None identified at this time | |
| | |

## 2. Watershed Characteristics and Conditions

**a. General Context/Overview of the Watershed**
The Armstrong Creek Watershed is 18,303 acres in size on the Atlantic Slope of the Blue Ridge Mountains in North Carolina. There are 8,462 acres of land managed by the National Forests in North Carolina located largely in the headwaters. Elevations range from 4,078 feet on the Blue Ridge Parkway to approximately 1,300 feet at the mouth into the North Fork Catawba River. The predominant land use in the Armstrong Creek Watershed is forested with low-volume roads accessing mostly the southern portion of the area. Forest Plan management areas emphasize scenery, wildlife habitat, timber supply, and backcountry area in the watershed. Private lands in the watershed are managed for forestry in the steeper mountains and agriculture, grazing, industry, and homes in the flatter areas.

**b. Watershed Conditions**
The watershed ranked "Fair" in the Watershed Condition Class analysis, but water quality is high with Armstrong Creek and many tributaries are designated by the state of North Carolina as High Quality Waters, supporting trout. These waters provide an important refuge for the propagation of aquatic organisms in the Catawba River Basin.

**3. Restoration Goals, Objectives, and Opportunities**

**a. Goal Identification and Desired Condition**
There is a need to treat non-native invasive plant species, improve aquatic passage at road crossings, improve terrestrial plant and wildlife habitats, and restore vegetation diversity in coves and streamside zones, large woody debris amounts to stream channels, and the fire regime. Implementation of these projects in the Armstrong Creek Watershed would shift the Watershed Condition Rating from "Fair" to "Good".

**b. Objectives**

**i. Alignment with National, Regional, or Forest Priorities**
This watershed condition work would be consistent with the Chiefs declaration of the general purpose of the Forest Service:

"to make sure that America's forests and grasslands are in the healthiest condition they can be; and to see to it that you have lots of opportunities to use, enjoy, and care for the lands and waters that sustain us all."

The proposed work would meet several aspects of the Regional Strategic Framework including: Aquatic organism passage improved (A.1.1); Watershed condition class is improved (A.1.2); Non-native invasive species controlled (A.2.1); Acres of restored native vegetation (A.2.2); Habitats of rare species are improved (A.3.3); Improve fire condition class strategically (B.1.1); Acres under Stewardship Authority (B.1.2); and Trails are maintained to standard or decommissioned (C.2.1).
Also, the proposed work would meet 2011 Forest Priority number seven - "Ecological Restoration in the Mountains" by increasing treatment of Non-Native Invasive Plant

species and increasing wildlife habitat restoration, and 2012 Forest Priority number two – "Collaboration/Integration/Stewardship" by developing and implementing a consistent process for Integrated Assessments. Direction in the Land and Resource Management Plan would be met as well.

ii. **Alignment with State or local goals**

The proposed work is in alignment with the state of North Carolina's goal to maintain the aquatic habitat and water quality that supports the designations of "Trout" and "High Quality Water" for Armstrong Creek and its tributaries.

**c. Opportunities**

i. **Partnership Involvement**

*Discuss the roles partners are expected to have within the priority watershed (overall planning, funding, etc.)* Stewardship opportunities are present within the Armstrong Creek Watershed. Potential partners include the National Park Service - Blue Ridge Parkway, The Nature Conservancy, American Chestnut Foundation, Southern Appalachian Forest Coalition, Western North Carolina Alliance, Southern Research Station, US Fish and Wildlife Service, NC Wildlife Resources Commission, the Ruffed Grouse Society, and the National Wild Turkey Federation. Groups such as these are likely to be involved in the planning process through proposal development and implementation by serving as primary and sub-contractors.

ii. **Outcomes/Output**

***a) Performance Measure Accomplishment***

The following performance measures are likely to be accomplished if the Essential Projects listed in Section d. are implemented:

1. Acres of hazardous fuels treated outside the wildland/urban interface (WUI) to reduce the risk of catastrophic wildland fire (FP-FUELS-NON-WUI)
2. Acres of forest vegetation improved (FOR-VEG-IMP)
3. Acres of Forest vegetation establishment (FOR-VEG-EST)
4. Miles of stream habitat restored or enhanced (HBT-ENH-STRM)
5. Number of stream crossings constructed or reconstructed to provide for aquatic organism passage (STRM-CROS-MTG-STD)
6. Miles of system trail improved to standard (TL-IMP-STD)
7. Manage noxious weeds and invasive plants (INVPLT-NXWD-FED-AC)
8. Acres of water or soil resources protected, maintained or improved to achieve desired watershed conditions (S&W-RSRC-IMP)
9. Acres of terrestrial habitat restored or enhanced (HBT-ENH-TERR)
10. Acres of forestlands treated using timber sales (TMBR-SALES-TRT-AC)
11. Volume of timber sold (CCF) (TMBR-VOL-SLD)

***b) Socioeconomic Considerations***

Implementation of the action plan would create jobs since much of the work would occur through contracts and agreements. The work would reinforce FS relationships within the community.

**d. Specific Project Activities (Essential Projects)**

**1. Prescribed Fire**

- Attribute/Indicator Addressed: 8.1
- Project Description: Implementation of prescribe burning approximately 1000 acres within the Armstrong Creek Watershed. This will restore and maintain habitat for *Hudsonia montana*, a federally threatened sub shrub that is dependent on periodic fire, in addition to abundant table mountain and pitch pine forests and woodlands. Fuel loads will also be reduced with these activities within the watershed. A moderate to high intense fire will be needed to meet the objectives. A helicopter will be needed to accomplish the prescribe burn due to moderate to steep terrain.
- Partners Involvement: National Park Service - Blue Ridge Parkway and The Nature Conservancy.
- Timeline: Starting in 2012 and continuing for 5 years.
- Associated Budget Line Item(s): CWKV, NFWF, and/or WFHF.
- Estimated costs:

| **Work Type** | **Cost** |
|---|---|
| Planning/NEPA | $20,000 |
| Prescribed Burn (@$150 x 1000 ac) | $150,000 |
| **Total**: | **$170,000** |

**2. Riparian Habitat Restoration**

- Attribute/Indicator Addressed: 3.2, 5.1, 9.1, 11.1
- Project Description: A combined treatment along stream courses in need of LWD inputs where significant high canopy loss resulted from eastern hemlock mortality. Restoration will be concentrated in areas with hemlock mortality and dense rhododendron. The treatment may include: (1) Directional felling (pushing snags using a track-hoe) of hemlock snags into stream channel; (2) Mechanical and chemical treatment of rhododendron to reduce its density; and (3) Planting of riparian hardwood species.
- Partners Involvement: NC Wildlife Resource Commission and NC State Fish Hatchery.
- Timeline: Starting in 2012 and continuing for 5 years.
- Associated Budget Line Item(s): NFVW, CWKV, NFWF, and/or Stewardship funding.
- Estimated costs:

| **Work Type** | **Cost** |
|---|---|
| Directional Pushing | $5,000 |
| Rhododendron Treatment | $8,000 |
| Tree Planting | $1,500 |
| NEPA | $8,000 |
| Monitoring stream LWD function & riparian treatment success ($1,000/year for 3 years) | $3,000 |
| Supplies | $4,000 |
| **Total**: | **$29,500** |

**3. American Chestnut Restoration**

- Attribute/Indicator Addressed: 12.1
- Project Description: Plant A. chestnut hybrid stock in small groups located along the Blue Ridge Parkway.
- Partners Involvement: American Chestnut Foundation and National Park Service.
- Timeline: Starting in 2012 and continuing for 5 years.
- Associated Budget Line Item(s): RTRT, NFVW, and/or Stewardship funding.
- Estimated costs:

| Work Type | Cost |
|---|---|
| Prescription/NEPA | $2,000 |
| Site Prep ($250/ac) | $500 |
| Planting ($500/ac) | $1,000 |
| Interpretation | $2,000 |
| Monitoring | $500 |
| **Total**: | **$6,000** |

4. **Rich Cove Forest Diversity Enhancement**
- Attribute/Indicator Addressed: 5.1,12.1 (Plus other terrestrial objectives)
- Project Description: The typical second or third generation rich cove forest is dominated by tulip poplars. Use thinning, regeneration, and planting techniques to increase the species diversity in selected cove forests within Armstrong WS. Desirable species will include but not be restricted to basswood, cucumber tree, white ash, beech, ironwood, black cherry, sugar maple and yellow buckeye.
- Monitor: Complete a third year sapling check by species.
- Partners Involvement: Southern Appalachian Forest Coalition, Western North Carolina Alliance, and Southern Research Station.
- Timeline: Starting in 2012 and continuing for 5 years.
- Associated Budget Line Item (s): NFTM, NFVW, RTRT, CWKV, NFWF and/or Stewardship funding.
- Estimated costs:

| Work Type | Cost |
|---|---|
| Prescription/NEPA ($17/ccf and 20ccf/ac over 100 ac) | $34,000 |
| Marking & Layout ($19/ccf) | $38,000 |
| Sell ($0.86/ccf) | $1,700 |
| Monitor ($25/ac Stocking check x 50 ac) | $1,250 |
| Regeneration and TSI ($225/ac x 50 ac) | $11,000 |
| **Total**: | **$85,950** |

5. **Aquatic Organism Passage (AOP)**
- Attribute/Indicator Addressed: 3.1
- Project Description: Replace existing FSR 469 culvert on Caney Creek with a structure that would allow passage of aquatic native species, such as Greenhead shiner.
- Partners Involvement: USFWS, NC Wildlife Resource Commission.
- Timeline: Starting in 2012 with NEPA & Design and construct within 5 years.
- Estimated costs and associated Budget Line Item (s): **$60,000** funded by NFWF, HTAP, CMLG, and/or other outside source.

6. **<u>Water Chemistry Data Collection – Base Cation Losses</u>**
   - Attribute/Indicator Addressed: 7.1
   - Project Description: The purpose of this project is to obtain water chemistry data. The assessment will identify which portions of the watersheds are likely to need restoration to replace base cation losses. Adequate supplies of base cations (calcium, magnesium, and potassium) in the soils are essential to maintain healthy forests and aquatic ecosystems. Additional inventory work will need to be completed after this project and before a base cation restoration project can be implemented.
   - Partners Involvement: Unknown at this time.
   - Timeline: Samples will be collected during spring base flow in 2012. Associated Budget Line Item: NFVW and/or FERC funding.
   - Estimated costs:

| **Work Type** | **Cost** |
|---|---|
| Water Samples - $150 Processing Fee for each of 10 samples | $1,500 |
| Forest Watershed Specialist plans & collects samples @ $430/day for 5 days | $2,150 |
| Enter site locations into NRIS @$430/day for 2 days | $860 |
| Fleet | $450 |
| Supplies | $100 |
| **Total**: | **$5,060** |

7. **<u>Trail Rehabilitation</u>**
   - Attribute/Indicator Addressed: 6.2 & 6.3.
   - Project Description: Change the FS Trail #223 designation from "Horse and Bike" to "Foot Traffic Only", and relocated sections of the same trail away from the stream and improve drainage e.g., by constructing rolling dips.
   - Partners Involvement: Unknown at this time.
   - Timeline: Starting in 2012 and continuing for 5 years.
   - Associated Budget Line Item: CMTL, CMLG, and/or Stewardship funding.
   - Estimated costs:

| **Work Type** | **Cost** |
|---|---|
| Design/NEPA (*complete with Timber Assessment*) | $2,500 |
| Construction | $15,000 |
| **Total**: | **$17,500** |

8. **<u>NNIS Treatments</u>**
   - Attribute/Indicator Addressed: 11.1
   - Project Description: Six non-native species; multiflora rose, princess tree, Chinese silvergrass, Japanese honeysuckle, Chinese yam and kudzu, have been documented primarily on the roadsides of the area as well as a few interior locations. In general the percent cover was low in these infested locations, less than 5%. The goal would be to control the infestations prior to any vegetative management project such as a prescribed burn or timber harvest. For most infestations species it will take two chemical

applications. For some species such as Chinese Yam, it may require at least 3 chemical applications.

- Monitoring: Revisit twenty 100 meter transects previously (2003) established along the road corridors recording percent cover of invasive plant species within three established zones (road edge, forest edge, and forest interior). Prior to implementing control establish an additional 20 transects within infestations on firelines, trails, stream courses, etc.
- Partners Involvement: National Park Service - Blue Ridge Parkway.
- Timeline: Starting in 2012 and continuing for 5 years.
- Associated Budget Line Item: NFVW, CWKV, and/or Stewardship funding**.**
- Estimated costs:

| **Work Type** | **Cost** |
|---|---|
| Inventory ($20/ac across at-risk acres) | $ 5,000 |
| Herbicide/Adjuvants | $ 500 |
| Control ($300/ac) for 100 acres | $30,000 |
| 2nd and 3rd control ($150/ac) for 50 acres | $15,000 |
| Monitor ($2500/year for 3 years) | $ 7,500 |
| **Total**: | **$58,000** |

**9. Rehab Drug Growing Site**

- Attribute/Indicator Addressed: 9.1
- Project Description: Ensure disturbed site is reforested with native species. Use appropriate shrub species, such as sweet pepperbush, and a grass species, such as Virginia wild rye or deer tongue grass that will reduce erosion impacts while still allowing nearby native species to reinvade the disturbed area.
- Monitor: Establish photo points across the acreage prior to planting, ensure at least 50-75% bare ground is covered with vegetation 1 year after planting and assess for any non-native invasive plant species.
- Partners Involvement: Unknown at this time.
- Timeline: Starting in 2012 and continuing for 5 years.
- Associated Budget Line Item(s): NFVW, RTRT, and/or CWK2.
- Estimated costs:

| **Work Type** | **Cost** |
|---|---|
| Prescription/NEPA | $5,000 |
| Plant ($500/ac for 1 acres) | $500 |
| Herb/Grass ($250/ ac for 1 acres) | $250 |
| Monitor photo points | $2,000 |
| **Total**: | **$7,750** |

**10. Wildlife Opening Habitat Enhancement**

- Attribute/Indicator Addressed: NA
- Project Description: Using silvicultural techniques to enhance habitat condition near wildlife openings through creating non-permanent openings, brushy interface, and savannah/woodland conditions.
- Partners Involvement: NC Wildlife Resource Commission.
- Timeline: Starting in 2012 and continuing for 5 years.
- Associated Budget Line Item(s): NFVW, NFTM, NFWF, and/or Stewardship.

- Estimated costs:

| Work Type | Cost |
|---|---|
| Prescription/NEPA ($17/ccf and 12ccf/ac (22 ac perm openings) | $4,500 |
| Marking & Layout ($19/ccf) | $5,000 |
| Sell ($0.86/ccf) | $2,300 |
| Monitor ($25/ac Stocking check x 50 ac) | $1,250 |
| Regeneration and TSI ($225/ac x 22 ac) | $5,000 |
| **Total**: | **$18,050** |

11. **Cerulean Warbler Habitat Enhancement**
- Attribute/Indicator Addressed: NA (until terrestrial portion shows up) (12.1 maybe)
- Project Description: Combinations of variable density thinning and regeneration techniques will be used to enhance vertical and horizontal stand diversity within selected stands to enhance late structural conditions and Cerulean Warbler habitat. The resulting habitat will have a diverse woody structure component in both the horizontal and vertical dimensions and contain more vigorous and a more resilient forest system.
- Partners Involvement: Bent Creek (SRS), Partners in Flight, NC Wildlife Resource Commission.
- Timeline: Starting in 2012 and continuing for 5 years.
- Associated Budget Line Item(s): NFVW, NFTM, NFWF, Stewardship, and CWKV (Assuming 12ccf/ac for a thinning/swd treatment average under a WL objective. Possible area of treatment = 150 acres of AMFC thin, 150 acres of RUMFC regen = 3,600 ccf ).
- Estimated costs:

| Work Type | Cost |
|---|---|
| Prescription/NEPA ($17/ccf) | $61,000 |
| Marking & Layout ($19/ccf) | $68,000 |
| Sell ($0.86/ccf) | $3,100 |
| Monitor ($25/ac Stocking check x 50 ac) | $1,250 |
| Regeneration and TSI ($225/ac x 75 ac) | $17,000 |
| **Total**: | **$150,350** |

12. ***udsonia montana* Habitat Enhancement**
- Attribute/Indicator Addressed: NA
- Project Description: Use non-commercial thinning techniques to reduce overstory density and treat competing shrub and herbaceous species to enhance habitat condition for HM. Post signs to reduce visitor impacts to *Hudsonia montana,* educating visitors to stay on the mountain-to-sea trail.
- Monitoring: Complete *Hudsonia montana* census within 4 separate size classes
- Partners Involvement: USFWS
- Timeline: Starting in 2012 and continuing for 5 years.
- Associated Budget Line Item(s): NFVW, RTRT, NFWF, and/or Stewardship.
- Estimated costs:

| Work Type | Cost |
|---|---|
| Prescription/NEPA (federal consultation) | $ 7,250 |

| | |
|---|---|
| Slash Treatment ($250/ac over 25 acres) | $ 6,250 |
| Signage | $ 3,500 |
| Monitor twice every third year | $ 3,000 |
| **Total:** | **$20,000** |

**e. Costs:**

| | Planning | Design | Implementation | Project Monitoring |
|---|---|---|---|---|
| FS Contribution | $169,310 | $127,000 | $312,100 | $19,750 |
| Partner Contribution (both in kind and $) | Unknown at this time | Unknown at this time | Unknown at this time | Unknown at this time |
| **Total** | $169,310 | $127,000 | $312,100 | $19,750 |

**Timelines and Project Scheduling**

| FY* | Task | | FS Cost | Partner cost |
|---|---|---|---|---|
| 2011 | **Prescribed Fire** | Planning/NEPA | $20,000 | Unknown |
| 2012-2013 | | Prescribed Burn | $150,000 | Unknown |
| 2012 | **Riparian Habitat Restoration** | NEPA | $8,000 | Unknown |
| 2013 | | Directional Pushing | $5,000 | Unknown |
| 2013 | | Rhododendron Treatment | $8,000 | Unknown |
| 2014 | | Tree Planting | $1,500 | Unknown |
| 2012 - 2014 | | Monitoring stream LWD function & riparian treatment success | $3,000 | Unknown |
| 2013 | | Supplies | $4,000 | Unknown |
| 2012 | **American Chestnut Restoration** | Prescription/NEPA | $2,000 | Unknown |
| 2013 | | Site Preparation | $500 | Unknown |
| 2013 | | Planting | $1,000 | Unknown |
| 2013 | | Interpretation | $2,000 | Unknown |
| 2013+ | | Monitoring | $500 | Unknown |
| 2012 | **Rich Cove Forest Diversity Enhancement** | Prescription/NEPA | $34,000 | Unknown |
| 2013 | | Marking & Layout | $38,000 | Unknown |

| | | | | |
|---|---|---|---|---|
| 2013+ | | Sell | $1,700 | Unknown |
| 2013+ | | Monitor | $1,250 | Unknown |
| 2014+ | | Regeneration and TSI | $11,000 | Unknown |
| 2013 | **Aquatic Organism Passage (AOP)** | Design | $3,000 | Unknown |
| 2012 | | NEPA | $7,000 | Unknown |
| 2013+ | | Construction | $50,000 | Unknown |
| 2012 | **Water Chemistry Data Collection – Base Cation Losses** | Water Samples - $150 Processing Fee for each of 10 samples | $1,500 | Unknown |
| 2012 | | Sample Collection | $2,150 | Unknown |
| 2012 | | Data entry into NRIS | $860 | Unknown |
| 2012 | | Fleet | $450 | Unknown |
| 2012 | | Supplies | $100 | Unknown |
| 2012 | **Trail Rehabilitation** | Design/NEPA | $2,500 | Unknown |
| 2013+ | | Construction | $15,000 | Unknown |
| 2013+ | **NNIS Treatments** | Inventory | $5,000 | Unknown |
| 2013+ | | Herbicide/Adjuvants | $500 | Unknown |
| 2013+ | | Control - 100 acres | $30,000 | Unknown |
| 2013+ | | 2nd and 3rd control for 50 acres | $15,000 | Unknown |
| 2013+ | | Monitor for 3 years | $7,500 | Unknown |
| 2012 | **Rehab Drug Growing Site** | Prescription/NEPA | $5,000 | Unknown |
| 2012+ | | Plant | $500 | Unknown |
| 2012+ | | Herb/Grass | $250 | Unknown |
| 2012+ | | Monitor photo points | $2,000 | Unknown |
| 2012 | **Wildlife Opening Habitat Enhancement** | Prescription/NEPA | $4,500 | Unknown |
| 2013+ | | Marking & Layout | $5,000 | Unknown |
| 2013+ | | Sell | $2,300 | Unknown |
| 2013+ | | Monitor | $1,250 | Unknown |
| 2013+ | | Regeneration and TSI | $5,000 | Unknown |
| 2012 | **Cerulean Warbler** | Prescription/NEPA | $61,000 | Unknown |

| | | | | |
|---|---|---|---|---|
| | **Habitat Enhancement** | | | |
| 2013+ | | Marking & Layout | $68,000 | Unknown |
| 2013+ | | Sell | $3,100 | Unknown |
| 2013+ | | Monitor | $1,250 | Unknown |
| 2013+ | | Regeneration and TSI | $17,000 | Unknown |
| 2012 | **Hudsonia *montana* Habitat Enhancement** | Prescription/NEPA (federal consultation | $7,250 | Unknown |
| 2013+ | | Slash Treatment over 25 acres | $6,250 | Unknown |
| 2013+ | | Signage | $3,500 | Unknown |
| 2013+ | | Monitor twice every third year | $3,000 | Unknown |
| ****FY of work depends on funding and workforce availability.*** | | | | |

f. **Other Partners:** We anticipate the proposed work in this document to involve partnerships with the following: U.S. Fish and Wildlife Service, NC Wildlife Resources Commission, NC State Fish Hatchery, National Park Service, The Nature Conservancy, American Chestnut Foundation, Southern Appalachian Forest Coalition, Western North Carolina Alliance, U.S. Southern Research Station (SRS), Bent Creek Experiment Station (SRS), and Partners in Flight.

**4. Restoration Project Monitoring and Evaluation**

**a. The forest will monitor:**

| **Project** | **Monitoring** |
|---|---|
| Riparian Habitat Restoration | Effectiveness monitoring - stream LWD function & riparian treatment success directly following completion of work. |
| American Chestnut Restoration | Effectiveness monitoring of plantings - complete a 3rd year sapling check. |
| Rich & Acidic Cove Diversity Enhancement | Effectiveness monitoring – complete a 3rd year sapling check by species. |
| Aquatic Organism Passage | Assess crossing for passage potential following construction to document passage improvement. |
| NNIS Treatment | Monitoring: Revisit twenty 100 meter transects previously (2003) established along the road corridors recording percent cover of invasive plant species within three established zones (road edge, forest edge, and forest interior). Prior to implementing control establish an additional 20 transects within infestations on firelines, trails, stream courses, etc. |
| Rehab Drug Growing Sites | Establish photo points across the acreage prior to planting, |

| | |
|---|---|
| | ensure at least 50-75% bare ground is covered with vegetation 1 year after planting and assess for any non-native invasive plant species. |
| Hudsonia montana Habitat Enhancement | Complete *Hudsonia montana* census within 4 separate size classes. |

b. **Monitoring will be done in cooperation with:** Unknown at this time.

**5. Contributors to this document**

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# Attachment 10

Nantahala National Forest National Forests in North Carolina
Transportation System Analysis Process (TAP) Report –
September 2015

# Nantahala National Forest
# National Forests in North Carolina
# Transportation System Analysis
# Process (TAP) Report

September 30, 2015

Recommended by:
Mike Wilkins, District Ranger, Nantahala Ranger District
Angela Gee, District Ranger, Cheoah and Tusquitee Ranger Districts

Reviewed by:
James Melonas, Acting Forest Supervisor
National Forests in North Carolina
USDA Forest Service
Southern Region

## Contents

## Executive Summary

Objectives of Forest-Wide Transportation System Analysis Process (TAP)
The objectives of the Forest-Wide TAP were to:

- identify key issues related to the Nantahala National Forest's transportation system, in particular affordability and cumulative effects;
- identify benefits, problems and risks related to the Nantahala National Forest's transportation system;
- identify management opportunities related to the existing transportation system to suggest for future consideration as National Environmental Policy Act (NEPA) decisions (examples included items such as road decommissioning within priority watersheds and needed aquatic passage improvement projects);
- create a map to inform identification of the future Minimum Road System (MRS);
- indicate the location of unneeded roads and possible new road needs.

(Note: Forest Service regulations at 36 CFR 212.5(b)(1) require the Forest Service to identify the minimum road system needed for safe and efficient travel and for administration, utilization, and protection of National Forest System (NFS) lands.)

## Analysis Participants

The TAP was conducted by an interdisciplinary team with extensive internal participation, and limited participation by partners and the general public. The primary participants were:

- Lynn Hicks, Team Lead, Forest Engineer, National Forests in North Carolina
- Angela Gee, District Ranger, Cheoah and Tusquitee Ranger Districts
- Mike Wilkins, District Ranger, Nantahala Ranger District
- Lee Thornhill, Forest Staff Officer, National Forests in North Carolina
- Steverson Moffat, NEPA Team Leader, Nantahala National Forest
- Bill Champion, Recreation Specialist, Tusquitee Ranger District
- Terry Eller, Forestry Technician, Cheoah Ranger District
- Bryan Killian, Timber Management Assistant, Nantahala Ranger District
- Jason Farmer, Fisheries Specialist, Nantahala National Forest
- Greg Brooks, Fire Management Officer, Nantahala Ranger District
- Chad Cook, Fire Management Officer, Tusquitee Ranger District
- Tim Solesbee, Fire Management Officer, Cheoah Ranger District
- Eric Pullium, GIS Editor, Nantahala National Forest
- Karl Buchholz, Forest Engineer, National Forests in North Carolina
- Cliff Northrop, Forest Engineer, National Forests in North Carolina

## Overview of the Nantahala National Forest's Road System

The Nantahala National Forest's road system currently comprises some 1,392 miles, providing access to approximately 526,637 acres of national forest, as well as to interspersed private tracts and nearby local communities. The system supports both recreation and resource management. It is comprised of a combination of old "public" roads, roads constructed to access timber sales and subsequent silvicultural activities, roads constructed to access recreation areas, and a variety of other routes. These range from double lane paved roads to single lane gravel or native surface roads that may be useable by passenger cars, to high clearance routes, to travel ways that are closed for periods of time greater than one year. Funding for the construction or reconstruction of all types was generally provided either by Congressional appropriations or authorized as a component of a timber sale. Maintenance funding is primarily by Congressional appropriations, although timber sales generally fund any maintenance required during the life of a particular sale operation.

## Issues, Benefits, Problems and Risks, and Management Opportunities Identified

- Current appropriations and supplemental revenue sources are not sufficient to adequately maintain the Nantahala National Forest's 1,392 mile road system as currently configured. Without changes, the existing road system requires an annual expenditure of approximately $2.12 million to maintain the road system in accordance with published standards. Only $263,400 are currently available, (Fiscal Year 2014 road maintenance budget), resulting in a shortfall of $1,855,090 or approximately 88%.

- There are 98 miles of system roads which primarily serve either as access to private inholdings, or as general access to adjacent communities. This figure represents 7% of total NFS system roads on the Nantahala National Forest. As opportunities allow, jurisdiction and maintenance should be considered for transfer to the most appropriate entity in order to allow the limited maintenance funding to be applied most effectively to the roads of the Nantahala National Forest.

- Certain roads, particularly those located relatively low in the watersheds, may be causing undue stress to water quality and associated aquatic organisms, especially if they cannot be regularly and properly maintained. This is particularly the case in watersheds that are classified as "impaired." The Upper Chattooga River is the only impaired watershed on the Nantahala National Forest. This watershed contains 4.04 miles of forest roads. Forest Service Roads are not a concern in this watershed.

- There appear to be opportunities to decrease the total system maintenance costs by decommissioning roads with highest risk and least benefit. One road segment was identified as low benefit, high risk, nine roads were identified as low benefit, medium risk, and 21 roads were identified for decommissioning by internal review, for a total of 26.09 miles.

- Twelve roads comprising 21 road segments totaling 34 miles are in areas where extra care should be used when considering road-related actions such as maintenance, reconstruction, or changing the road management level based on aquatic biota vulnerability risk.

- There are a number of roads that will most likely be needed at some time in the future, but which do not appear to be needed for actions currently being proposed. Storage of these roads (closure for at least a year, with only custodial maintenance provided) should be strongly considered. TAP analysis suggests that 39 miles should be considered for conversion to storage and custodial maintenance only until needed.

- To meet budgetary limitations some roads currently opened year round will need to be identified to be considered for seasonal closure (65.34 miles); and some roads currently maintained for passenger car use (currently in Maintenance Levels 3, 4, or 5) will need to be identified to be considered for conversion to high clearance use only (29.3 miles).

- Relatively high road densities may be impacting some sensitive wildlife species in a few specific areas of the forest. Overall, however, road densities do not exceed those allowed by the forest plan. As configured the overall road density, exclusive of non-FS roads, is 1.77 miles/square mile, and open road density is .63 miles/square mile.

- Several roads or portions of roads may have to be closed due to insufficient bridge replacement funding. There are 42 bridges on the Nantahala National Forest located on open roads, and 21 are load restricted or otherwise deficient.

- Opportunities should be sought to increase road maintenance revenues where possible through the use of stewardship contracts and partnerships, including volunteer groups, such as hunters, anglers, hikers, equestrian organizations, and others.

## Comparison of Existing System to Minimum Road System as Proposed by TAP

Refer to Appendix F for a summary of proposed changes to the existing road system suggested by the TAP, as information available to frame future NEPA analysis and decisions.

## Next Steps

- TAP recommendations will be used to inform NEPA decisions, many of which will eventually be implemented in conjunction with various restoration projects on the Forest.
- Prior to implementing these recommendations, NEPA determinations will be conducted at appropriate scales, using the TAP to inform issues, particularly effects and affordability.
- The road system should be revisited with an updated forest-wide TAP, probably on about a 10 year cycle, with the next one due by perhaps the year 2025.

## Context

### Alignment with National and Regional Objectives

Sub-Part "A" Travel Analysis is required by the 2005 Travel Management Rule (36 CFR 212.5). Forest Service Manual 7712 and Forest Service Handbook 7709.55-Chapter 20 provide specific direction, including the requirement to use a six step interdisciplinary, science-based process to ensure that future decisions are based on an adequate consideration of environmental, social and economic impacts of roads. A letter from the Chief of the Forest Service dated March 29, 2012 was issued to replace a November 10, 2010 letter previously issued on the same topic. It reaffirms agency commitment to completing travel analysis reports for Subpart A of the travel management rule by 2015, and also provides additional national direction related to this work, addressing process, timing and leadership expectations. The letter requires documentation of the analysis by a travel analysis report, which includes a map displaying the existing road system and possible unneeded roads. It is intended to inform future proposed actions related to identifying the minimum road system. The TAP process is designed to work in conjunction with other frameworks and processes, the results of which collectively inform and frame future decisions executed under NEPA. This letter is included in Appendix G.

The document entitled "Sub-Part "A" Travel Analysis (TAP), Southern Region Expectations, Revised to align with 2012 Chief's Letter" and attached in Appendix H, supplements the national direction for Forest Scale TAPs developed for the Southern Region.

### Coordination with Forest Plan

The current Forest Plan for the Nantahala National Forest's was adopted in 1994. It provides specific direction for overall management of the Nantahala National Forest. The forest-wide TAP tiers to the Nantahala National Forest's Forest Plan by informing future NEPA actions that implement the Forest Plan and have transportation components. The TAP has been informed by the Watershed Condition Framework, and likewise, the TAP is intended to inform future forest restoration activities, including watershed restoration.

### Budget and Political Realities

The roads located on the Nantahala National Forest are a combination of historic trails that have undergone improvement over the years, roads that were built to access timber sales, roads constructed for access to communities, either internal or adjacent to the forest, roads constructed for recreational opportunities, and roads constructed or otherwise acquired through a variety of means to comprise the current system. As is the case for much of the rest of the infrastructure on the forest, funding has been inadequate to properly maintain all of the forest's roads and bridges. In some cases these roads and bridges have become superfluous to our administrative needs, and many no longer meet public needs either. From 2008 to 2010, the Nantahala National Forest decommissioned 29 miles of roads. Changes are becoming inevitable, being driven both by the budget as well as by the need to have the most efficient and effective transportation system on the ground as possible, and no more. The TAP process is an attempt to begin to identify a proposed "minimum road system" (MRS) which will only come into place as NEPA decisions are made and then actual on-the-ground decisions are implemented. The MRS will probably change over time as well, as public needs and financial resources change. Therefore it is expected that new forest-wide TAP analyses will continue to be needed, probably on about a 10 year cycle.

## 2012 Transportation Bill Effects (MAP-21)

MAP-21, the Moving Ahead for Progress in the 21st Century Act (P.L. 112-141), was signed into law by President Obama on July 6, 2012 and authorizes the Federal Lands Transportation Program (FLTP) for two years (2013 – 2014). Extensions of this bill are expected until a new reauthorization is enacted. The FLTP provides dedicated funding to improve access within Federal lands owned by the Federal government. Of the $300 million allocated for this program, the USDA Forest Service competes with the Bureau of Land Management (BLM) and the US Army Corps of Engineers for up to $30 million per year. The central theme of the program is performance management. As amended by MAP-21, 23 U.S.C 203(c) requires the USDA Forest Service along with the other four core partners eligible for FLTP funding to define the part of its transportation system to be included in the FLTP. In addition, a baseline condition for this system should be determined and progress on the improvement of this system should be reported annually to FHWA.

The projects to be funded by the FLTP are selected by the Region 8 (Southern Region) Regional Forester with input from the Region 8 Director of Engineering. The amount of funding that each Forest unit receives varies from year to year depending on the priorities for the region. To date the Nantahala National Forest has not received any FLTP funding.

Under MAP-21, the Forest Highway program was repealed and in its place a new program, the Federal Lands Access Program (FLAP), was created. This program differs from the old Forest Highways program in that funding is available to improve access to all federal lands and not just national forests. Similar to the Forest Highway program, FLAP transportation projects are funded for infrastructure that is under State, county or other local government's jurisdiction. No road network needs to be designated and, as a result, no projects located on the NFSR system are eligible for FLAP funding.

## Alignment with Watershed Condition Framework (WCF)

Along with the other national forests across the country, Nantahala National Forest recently conducted an analysis of its watersheds, categorized them as to their condition and prioritized them for future efforts at improvement. Three categories were identified: Class 1 – Functioning Properly, Class 2 – Functioning at Risk, and Class 3 – Impaired Function. These classifications were performed on watersheds at the 6th order hydrologic unit classification (HUC) according to procedures described in the "Watershed Condition Framework" technical guide, http://www.fs.fed.us/publications/watershed/Watershed_Condition_Framework.pdf. It identified 10 watersheds on the Nantahala National Forest as Class 1, 88 as Class 2 and one as Class 3. Maps showing all 6th order watersheds by ranger district can be found in Appendix I. The **Upper**

**Chattooga River** watershed was selected as a priority watershed for focus work in the next decade. The priority watershed may be found on the maps in Appendix I.

The forest-wide TAP analysis was heavily informed by the WCF. For example, roads located near streams within impaired watersheds, and especially priority impaired watersheds, were considered as possible decommissioning candidates. Similarly, continuing watershed improvement work is intended to be informed in the future by the TAP.

## Overview of the Nantahala National Forest and supporting Transportation System

### General Description of the Nantahala National Forest Land Ownership Patterns, Land Use and Historic Travel Routes

The Nantahala National Forest is comprised of 526,637 acres, occupying almost 40% of the proclamation boundary. Almost all is forested, with about 52,369 acres (or 10%) being Wilderness or otherwise classified as Roadless, and 474,268 acres (or 90%) being available for active forest management. Interspersed within the proclamation boundary, and adjacent to the National Forest are several large tracts managed as TIMOs (Timber Investment Management Organizations) or REITs (Real Estate Investment Trusts) as well as some scattered large forest industry tracts, some small farms and a variety of other ownership types. There are a few small communities within the proclamation boundary as well, the larger ones being Murphy, Franklin, and Robbinsville. When the land came under the ownership of the Nantahala National Forest it was riddled with a legacy of historic travel routes that were primarily located low in the water-sheds, alongside stream channels, presumably as these were the simplest locations on which to construct primitive travel ways. Over the past few decades the Nantahala National Forest has been working towards relocating many of these roads up the slopes and away from the streams.

The lands of the Nantahala National Forest are administered by three ranger districts, the Cheoah, Nantahala, and Tusquitee. The number of acres administered by each district is:

| District | Acres | Portion that is Roadless |
|---|---|---|
| **Cheoah** | 122, 095 | 19,466 |
| **Nantahala** | 244, 638 | 10,858 |
| **Tusquitee** | 159, 904 | 22,315 |
| **Totals** | **526,637** | **52,369** |

There are 66 developed recreation areas on the Forest, including the Nantahala River, Standing Indian Campground, Jackrabbit Mountain Campground, the Tsali Recreation Area, Joyce Kilmer Memorial Forest, Dirty John Shooting Range, Moss Knob Shooting Range, Atoah Shooting Range, Panthertop Shooting Range, and Wayahutta Off Highway Vehicle Area. Dispersed recreation is allowed throughout the Nantahala National Forest with only limited exceptions. Also, there are 763 miles of trails, supporting a variety of uses, including equestrian, biking, pedestrian, and mixed use. Motor vehicles are restricted to roads shown on the Motor Vehicle Use Map (MVUM) included in Appendix C.

## Description of the Nantahala National Forest's Transportation System

Several Federal and State highways, including U.S. Highways 19, 64, 74, 129 and State Highways 441, 28, 107, and 281 traverse various parts of the Nantahala National Forest. Some of these roads comprise a portion of the 124 miles of Forest Highway, which provides access to relatively large tracts of the Forest. Forest Highways are roads maintained under another agency's jurisdiction, which on occasion receive reconstruction project funding through the Highway Trust Fund.

There are 1,392 total miles of National Forest system road under the jurisdiction of the Nantahala National Forest. This mileage is comprised of 409 miles suitable for passenger car use, almost all of which are open to the public on a year round basis, 635 miles only suitable for high clearance vehicular traffic, of which 46 miles are open to the public year round and 71 miles which are at least seasonally closed. There are 360 miles on the system inventory that are closed for periods of time greater than one year, being in "storage" for future use when needed.
The Forest Service catalogs its roads in the official inventory, I-Web, by Maintenance Levels, loosely defined as follows:

- Maintenance Level 5 – Single or double lane paved roads w/ high degree of user comfort
- Maintenance Level 4 – Moderate comfort; primarily double lane aggregate roads w/ ditches
- Maintenance Level 3 – Lowest level maintained to accommodate passenger car traffic
- Maintenance Level 2 – Maintained primarily to accommodate use by high clearance vehicles
- Maintenance Level 1 – Closed to all traffic for periods greater than one year.

Table 1 shows the current break down of the Nantahala National Forest's road system by maintenance level:

**Table 1. Nantahala National Forest's Road System Mileage by Maintenance Level.**

| | ML 1 | ML 2 | ML 3 | ML 4 | ML 5 |
|---|---|---|---|---|---|
| **Cheoah** | 71.18 | 203.87 | 56.39 | 24.2 | 4.97 |
| **Nantahala** | 206.65 | 312.04 | 114.02 | 42.52 | 26.54 |
| **Tusquitee** | 82.17 | 109.88 | 96.77 | 35.29 | 5.31 |
| **Forest Totals** | **360** | **625.79** | **267.18** | **102.01** | **36.82** |

## Private and Co-op Roads

Certain roads located on the Nantahala National Forest are needed to provide access to private tracts of land, or by municipalities or large private landowners in cooperation with the Forest. The maintenance responsibility for and jurisdiction of these roads are identified in the official inventory. Generally costs for maintaining these roads are pro-rated to the appropriate benefitting entity, as further specified in the enabling agreements.

## Unauthorized Roads

At any given time there may be roads found to be in existence on the landscape that are not shown in the inventory or on an official map. These roads are considered to be unauthorized roads, unneeded for use by the Nantahala National Forest. They are subject to decommissioning at any time funding becomes available for that purpose.

## Road Maintenance Funding

The Nantahala National Forest maintains its road system primarily with funding provided through the annual Interior and Related Agency's budget, specifically the CMRD line item. The Nantahala National Forest received $263,400 of this funding in fiscal year 2014. Another source of revenue available for certain types of maintenance on the Nantahala National Forest's road system is the CMLG line item. A total of $387,500 of the CMLG budget line item was received in FY 2014, of which $55,000 was available for road repair. Roads that support management operations may be maintained with timber sale or stewardship dollars during the life of the operation, but that is not typically a long term solution. Finally, partners and user groups may provide road maintenance support. In 2014 the Nantahala National Forest received $30,000 worth of partner and user support, either in cash or in on-the-ground value related to the road system, primarily from the North Carolina Wildlife Resources Commission mowing 100 miles of grassed roads managed as linear wildlife openings.

# Cost of Operating and Maintaining the National Forest's Roads and Bridges

## Operations Costs

As presented in the previous section, there is on an annual basis a total of approximately $263,400 available with which to operate and maintain the Nantahala National Forest's road system. Of this, approximately $57,000, or 21%, is required to cover fixed costs, including management salaries, rent, fleet, travel and training and cost pool contributions. This amount also covers items such as data management, contract preparation and administration and upward reporting. Regardless of the size of the road system being managed this base amount is required. This leaves only about $207,000 to go on the ground for actual maintenance of the road system, and it must cover replacement of deficient bridges as well.

## Road Maintenance Costs

Refer to Table 2 for costs associated with the primary components of road maintenance, per mile, on the Nantahala National Forest. In addition to inspections, these include: (1 & 2) blading and ditching, (3) culvert cleaning (4) culvert replacement, (5) bridge inspections, (6) bridge replacement, (7) gate repairs / signage, (8) gate replacement, (9) road signage replacement, (10) ABC / asphalt replacement, (11) mowing / brushing, (12) moderate storm damage removal, and

(13) slide removal. Table 2 displays typical costs for these maintenance practices on the Nantahala National Forest's road system by activity and road maintenance level:

**Table 2. Typical Unit Costs for road maintenance components on the Nantahala National Forest, per mile.**

| Description | ML5 | ML4 | ML3 | ML2 | ML1 |
|---|---|---|---|---|---|
| Blading | $436.07 | $641.34 | $255.16 | $23.65 | NA |
| Ditching | $156.24 | $153.19 | $136.53 | $16.95 | NA |
| Culvert Cleaning | $1,000.00 | $500.00 | $445.64 | NA | NA |
| Culvert Replacement | $531.42 | $531.42 | $531.42 | $531.42 | NA |
| Bridge Inspections | $105.00 | $60.00 | $30.00 | $8.00 | $0.00 |
| Gate Repairs/Signage | $28.44 | $3.59 | $7.17 | $19.78 | $24.54 |
| Gate Replacement | $118.52 | $14.97 | $29.88 | $82.43 | $102.23 |
| Road Signage Replacement | $936.00 | $534.00 | $330.00 | $165.00 | NA |
| ABC/Asphalt Replacement | $8,453.39 | $5,000.00 | $2,408.25 | $55.31 | NA |
| Mowing/Brushing | $500.00 | $500.00 | $451.53 | $333.33 | $21.81 |
| Moderate Storm Damage Removal | $128.30 | $139.33 | $182.43 | NA | NA |
| Slide Removal | $66.15 | $71.84 | $94.06 | NA | NA |

## Bridge Maintenance and Reconstruction Costs

The Nantahala National Forest has 42 bridges and nine major culverts. These have to be inspected every other year, with costs varying per bridge by maintenance level, and which averaged $350.00 per bridge in 2012. (b) (5) [redacted] Typical bridge replacement costs for the Nantahala National Forest are about $150 per square foot for a typical two lane bridge. These costs need to be added to the total road maintenance costs above to get a true picture of the total road and bridge maintenance costs for the next 10 years on the Nantahala National Forest.

## Total Cost of Operating and Maintaining the Nantahala National Forest's Roads and Bridges to Standard

The combined information from the previous sections is presented in Table 3, page 10, which shows the total annual cost to maintain the Nantahala National Forest's roads and bridges to standard as the system currently exists.

**Table 3: Cost to Maintain Roads and Bridges**

| Item | Number | Unit Cost | Total Cost |
|---|---|---|---|
| Fixed Cost to Operate | 1 | $57,000 | $57,000 |
| Maintenance of Level 1 Roads | 360 miles | Varies† | $241 |
| Maintenance of Level 2 Roads | 625.79 miles | Varies† | $63,944 |
| Maintenance of Level 3 Roads | 267.18 miles | Varies† | $820,232 |
| Maintenance of Level 4 Roads | 102.01 miles | Varies† | $553,019 |
| Maintenance of Level 5 Roads | 36.82 miles | Varies† | $393,204 |
| Inspection of ½ of Bridges each Year | 21 | $350 | $7,350 |
| Replacement of Deficient Bridges | 1 per year | $223,500 | $223,500 |
| **Total Annual Cost** | | | **$2,118,490** |

†Costs can be incurred annually, every other year, or every third year. Dividing total cost by miles of road does not produce a statistically valid cost-per-mile.
A number of roads managed as linear wildlife openings are mown through a cooperative agreement with the North Carolina Wildlife Resources Commission, resulting in substantially reduced management costs for the Nantahala National Forest.
Note: Compare current available budget of $263,400 to the needed amount of $2.12 million.
Note: Appendix E in Section H shows the cost of maintaining the "suggested" Minimum Road System" which balances costs and revenue.

## Assessment of Issues, Benefits and Risks

### Financial

The primary financial issues relate to the inability to adequately maintain the existing road system with current funding sources. As indicated previously, there is on an annual basis a total of approximately $263,400 available with which to operate and maintain the system, whereas the needed funding for the system as currently configured is about $2.12 million. By spreading maintenance costs and practices over periods as long as three years and through cooperative agreements with the North Carolina Wildlife Resources Commission to mow roads maintained as linear wildlife openings, the actual amount needed to maintain the present road system per year, less bridge replacement, is approximately $1.85 million. Deferred maintenance continually accrues on the system, but more importantly, it is a challenge to maintain Best Management Practices (BMPs) required to minimize nonpoint-source water pollution to maintain water quality and associated aquatic life. Roads and bridges may develop safety hazards and could have to be closed, with the system (1) potentially failing to meet the needs of both the recreating and travelling public, and (2) failing to provide adequate access for forest management activities, including prescribed fire and fire suppression.

### Environmental and Social

The primary environmental impacts from the road system are related to (1) erosion of the roadbed, cut slopes, fill slopes and ditches, with the resulting sediment discharge affecting water quality and associated aquatic resources; (2) in some cases, open road density effects on certain wildlife species, such as black bears; and (3) the roads serving as a conduit for invasive species. In the social arena, the effects are primarily the demand for adequate access, sometimes offset by the need for providing solitude. Additionally, law enforcement faces challenges due to the high demand. Access is needed by a variety of forest users, including hikers, hunters, fishermen and other recreationists, as well as for management activities such as restoration projects and fire suppression. Also, roads require surveillance, as they can become sites for crime, illegal dumping and similar activities.

## Safety and Function

The primary issues related to safety and function of the Nantahala National Forest's road system include (1) maintenance of a clear and smooth travel way, (2) access in the proximity of the use, (3) steep road grades, (4) functioning of the drainage features, (5) width and stability of the road bed, (6) proper signs and markings, (7) and structurally and functionally sufficient bridges.

## Measurement and Rating

Benefits and Risks of the overall system were tabulated and appear in Appendix D. The standard list of questions in the Forest Service Handbook was used as a guide to further assist in identifying the benefits and risks. The degree of risk was rated subjectively as being high, medium or low for the system by appropriate specialists. Then, after considering the entire system, each road was also considered. Those with particular issues, benefits and/or risks different from those of the entire system were listed and further described below for further consideration. As related projects become identified at some time in the future, this list may be referenced to inform projects or proposed changes in the Minimum Road System.

(b) (5)

[redacted]

(b) (5) [redacted]

## Recommendations and Proposed Mitigation Measures

### Rationale Used to Arrive at Proposed Minimum Road System

The Chief's March 29, 2012 letter reaffirms that "the Agency expects to maintain an appropriately sized and environmentally sustainable road system that is responsive to ecological, economic, and social concerns. The national forest road system of the future must continue to provide needed access for recreation and resource management, as well as support watershed restoration and resource protection to sustain healthy ecosystems." Roads which are not needed cannot be supported in the future. Roads that primarily provide access to the public or to a local community need to be considered for transfer of maintenance responsibility, as appropriate. A total of 98 miles in 73 road segments were identified that should be considered in this category.

Roads which have little benefit yet which have high and medium risks to various environmental or social values were flagged for consideration as decommissioning candidates, as were additional road segments that were recommended for decommissioning based on internal review. (b) (5) [redacted]

Roads that did not appear to be currently needed for project access during the next decade, and which appear currently to be receiving extremely low use by the public or which appear to not be otherwise needed for management purposes such as fire suppression access were flagged to be considered for storage; (b) (5) [redacted] Some roads which are primarily needed only for administrative use, or by hunters and which are currently useable by passenger vehicles were recommended to be considered for conversion to the high clearance. (b) (5) [redacted] which are receiving the highest amount of use, especially by

(b) (5)

[redacted]

(b) (5)

[redacted]

## Miles by Proposed as Unneeded, by Watershed Condition Class

The Upper Chattooga River is the only impaired watershed on the Nantahala National Forest. This watershed contains 4.04 miles of forest roads.

## Suggested Conversion of Existing Road System to Minimum Road System

Table F in the Appendices presents proposed changes in maintenance level between the existing road system and the optimal future road system. Although some roads have been suggested to comprise these changes, there are others which have not yet been identified. During the next decade the suggested changes in overall road system makeup should inform projects, and additional individual road change proposals will be identified, with the goal of achieving the proposed minimum road system, and associated financial sustainability as quickly as is practical.

## Best Management Practices (BMPs) Applicable to the Nantahala National Forest

When maintaining the forest roads located on the Nantahala National Forest the following Best Management Practices should be adhered to as a minimum:

- National Best Management Practices for Water Quality Management on NFS Lands
- Applicable State Best Management Practices
- Best Management Practices listed in the current Forest Plan.
- Completed Watershed Action Plans

# Appendices

A. Map of Existing Road System
B. Map of Proposed Unneeded Roads
C. Motor Vehicle Use Map(s) MVUMs
D. Tabular Summary of Existing Road System Showing Benefits and Risks
E. Spreadsheets of Existing Road System and Suggested MRS showing Maintenance Costs
F. Comparison of Existing and Suggested Minimum Road Systems (miles by ML)
G. Chief's Letter of Direction
H. Southern Region Expectations
I. 6th Level HUCs Watershed Condition Classifications and Priority Watersheds

## Appendix A – Map of the Existing Road System.

This is an oversized document, therefore only the link is provided:

(b) (5) [redacted]

## Appendix B – Map of the Unneeded Roads.

This is also an oversized document, therefore only the link is provided:

(b) (5) [redacted]

## Appendix C – Motor Vehicle Use Maps.

This is also an oversized document, therefore only the link is provided:
http://www.fs.usda.gov/main/nfsnc/maps-pubs

(b) (5) [redacted]

## Appendix D – Existing Road System Benefits and Risks

| Recreation Benefit | |
|---|---|
| Information on the amount and types of recreation uses was developed at meetings with district personnel, other public agency representatives, members of the public, and from LRMP management area designation. | HIGH (2):<br>Road accesses major developed recreation complex and/or a wide variety of high use dispersed recreation opportunities. |
| | MEDIUM (1):<br>Road accesses minor developed recreation area(s) and/or a variety of moderately used dispersed recreation opportunities. |
| | LOW (0):<br>Road accesses only minor dispersed recreation opportunities and/or non-motorized use is emphasized (MA 3, MA 4, or other special area MA), or the road's close proximity to Wilderness or other area with special characteristics is producing negative impacts. |

| Social Benefit | |
|---|---|
| Information on the amount and types of social uses was developed at meetings with district personnel, members of the public, and Eastern Band of Cherokee. | HIGH (2):<br>There are long-standing traditional uses accessed by the road and/or the road is an important through road for local users. |
| | MEDIUM (1):<br>There may be some traditional uses accessed by the road or the road offers some convenience to local travelers. |
| | LOW (0):<br>There are few if any traditional uses accessed by the road and/or non-motorized use is emphasized (MA3, MA4, or other special area MA). |

| Resource Management Benefits | |
|---|---|
| To assign a value for resource management, an analysis was performed to establish how much access a road provides to resource management areas. The amount of access is not only that directly provided by the open road in question, but also from closed system roads that adjoin the open road in question. Roads were rated accordingly: | HIGH (2):<br>More than 2.0 miles of road accesses land for resource management |
| | MEDIUM (1):<br>More than 0.5 mile and less than 2.0 miles of road accesses land for resource management |
| | LOW (0):<br>Less than 0.5 mile of road is accesses land for resource management |

| Fire Management Benefit |
|---|
| The two primary functions affected within Fire Management are Fuels Management and Fire Suppression. Values are assigned based on the topography, fire history and the relationship of that particular road or area to the area as a whole. The Fire Management Benefit score is the sum of Fuels Management Benefit and Fire Suppression Benefit scores, below, and ranges from 0 to 3. |

| Fuels Management Benefit | |
|---|---|
| Fuels Management consists of actively mitigating potential fire behavior by manipulating the fuels amount and arrangement in a given area. | HIGH (2):<br>Due to other constraints the roadbed is the only access to areas planned for future treatment, or for accomplishment of treatments currently ongoing in the area. |
| | MEDIUM (1):<br>Roadbed is necessary to provide cost effective access for fuels treatment projects, or provides a necessary addition to otherwise occurring human-caused or naturally occurring fuel breaks or barriers in decreasing fuel continuity. |
| | LOW (0):<br>Road is not deemed necessary for the current fuels treatments planned or being considered. Fuel arrangement and/or availability are mitigated through other permanent human-caused or natural fuel breaks or barriers. |

| Fire Suppression Benefit | |
|---|---|
| Positive need for a road is established by the degree to which the road may allow for more safe and/or efficient fire suppression efforts within the area. Factors to consider include strategic location, navigable terrain, and having vistas of the surrounding environment. | HIGH (2):<br>The road provides for a significant firebreak in areas requiring a permanent fuel break such as between forested areas and residential areas, or the road lessens the risk for firefighters and the public by providing necessary access and/or egress to areas having a high fire occurrence risk. |
| | MEDIUM (1):<br>The road, in conjunction with time-of-need improvements or other local topographical features provides for a useable fire line or fire break, or provides some degree of usable access to otherwise inaccessible areas. |
| | LOW (0):<br>Fire suppression activities are not directed or affected by the presence of the road. Equally the roads may or may not be used for suppression forces or tactics |

| Other Unique Benefits |
| --- |
| This category considers other unique benefits provided by the road, which are not described by other categories. This score can range from 0 to 2. Most roads should have a zero in this category. |

| Traffic Volume Benefit | |
| --- | --- |
| Traffic volume brings both value and risk to a road. On the risk side, high traffic volumes are associated with more risk to public safety and wildlife. On the value side, traffic volume is considered as a surrogate for need. A road with high traffic volume is a road that serves some purpose in the lives of many people. However, even a low volume road may provide a need for certain individuals. | HIGH (2):<br>MEDIUM (1):<br>LOW (0): |

| Aquatic Biota Vulnerability Risk | |
| --- | --- |
| Aquatic biota vulnerability is a indicator that factors are associated with this road that mandate extra care be used when considering road-related actions such as maintenance, reconstruction, or changing the level or type of use. In determining the vulnerability rating, the following factors were used: % of road paralleling stream; number of stream crossings; presence of trout (management indicator species); presence of brook trout. | HIGH (2):<br>MEDIUM (1):<br>LOW (0): |

| Risk to Rare Species and Habitats | |
|---|---|
| A GIS analysis was performed to determine roads within 200 feet of any element occurrence of a threatened, endangered, or sensitive species; within 200 feet of a special habitat such as bogs and rock outcrops; or within 200 feet of designated old growth. | HIGH (2):<br>More than one element occurrence of a T&E species, or one T&E element occurrence and at least one other factor |
| | MEDIUM (1):<br>One element occurrence of a threatened or endangered (T&E) species, or one or more other factors are present. |
| | LOW (0):<br>None of the above factors occurs within 200 feet of the road |

| Risk to Wildlife | |
|---|---|
| The factors used to assign wildlife-associated risks to roads included: extremely excessive open road density in a management area "4;" poaching is known to have occurred; proximity to bear sanctuary; and high traffic volume. | HIGH (2):<br>More than two of the above risk factors are present. |
| | MEDIUM (1):<br>One or two of the above risk factors is present. |
| | LOW (0):<br>None of the above risk factors is present. |

| Wildfire Suppression Risk | |
|---|---|
| The risks are associated with providing a road that is an apparent tool, which upon further inspection increases the overall hazards of the suppression efforts. A road would be valued negatively overall if it seemingly provides access only to effectively draw a crew into an entrapment situation. The current use of crews from out of the local area and the availability of aircraft for both reconnaissance and suppression were factors in determining the risk rating of some of the roads. | HIGH (2):<br>The roadbed is not maintained to support larger, heavier equipment. The road dead-ends with limited or no options to turn equipment around. Limited sight distance. Switchbacks are sharp, steep or routinely rutted/rained out. The roadbed follows along or crosses into the bottom of a drainage. The road ownership patterns make it hard to predict obstacles or hazards |
| | MEDIUM (1):<br>The road doesn't enhance the safety of firefighters or the public. The roadbed and or the surrounding fuels are not situated or maintained to provide a safety zone more effectively than naturally occurring openings in the area. The road has limited access/egress opportunities. |
| | LOW (0):<br>The road and turnouts are adequate for controlled moderate to heavy traffic and the roadbed including switchbacks are maintained to provide safe passage of larger or heavier fire suppression equipment. Sight distances are adequate. The road has multiple access points. |

| Heritage Resources Risk | |
| --- | --- |
| A GIS analysis was performed to determine roads within 200 feet of any known archeological sites or areas. In addition, the Forest archeologist and Eastern Band of Cherokee Indians provided additional information | HIGH (2):<br>Four or more sites per mile of road |
| | MEDIUM (1):<br>Two or three sites per mile of road |
| | LOW (0):<br>Less than two known sites per mile of road |

| Risk to Public Safety | |
| --- | --- |
| Public safety is a critical factor in managing the transportation system. The following factors were considered in assigning a public safety risk to each road: presence of pedestrian traffic; amount of vehicular traffic; amount of year road is open; condition of road; excessive speed identified as issue; other identified law enforcement issue; other identified safety issue. | VERY HIGH (3): |
| | HIGH (2): |
| | MEDIUM (1): |
| | LOW (0): |

| Maintenance Cost Risk | |
| --- | --- |
| The shortfall in maintenance dollars is one reason the Roads Analysis Process regulations were passed. Because funding is not adequate for identified needs, those roads with higher total road maintenance needs, including annual and deferred, are a higher risk for health and safety and resource damage. A risk factor is assigned to each road based on the total cost of maintenance per mile. Table V-12 displays a summary. | VERY HIGH (3):<br>> $50,000 per mile |
| | HIGH (2):<br>$25,000 - $49,999 per mile |
| | MEDIUM (1):<br>$7,500 - $24,999 per mile |
| | LOW (0):<br><$7,500 per mile |

## Appendix E –Current and Potential Future Maintenance Costs

**Current annual costs of maintaining the Nantahala National Forest's existing roads and bridges, per mile.**

| Description | ML5 | ML4 | ML3 | ML2 | ML1 |
|---|---|---|---|---|---|
| Blading | $436.07 | $641.34 | $255.16 | $23.65 | NA |
| Ditching | $156.24 | $153.19 | $136.53 | $16.95 | NA |
| Culvert Cleaning | $1,000.00 | $500.00 | $445.64 | NA | NA |
| Culvert Replacement | $531.42 | $531.42 | $531.42 | $531.42 | NA |
| Bridge Inspections | $105.00 | $60.00 | $30.00 | $8.00 | $0.00 |
| Gate Repairs/Signage | $28.44 | $3.59 | $7.17 | $19.78 | $24.54 |
| Gate Replacement | $118.52 | $14.97 | $29.88 | $82.43 | $102.23 |
| Road Signage Replacement | $936.00 | $534.00 | $330.00 | $165.00 | NA |
| ABC/Asphalt Replacement | $8,453.39 | $5,000.00 | $2,408.25 | $55.31 | NA |
| Mowing/Brushing | $500.00 | $500.00 | $451.53 | $333.33 | $21.81 |
| Moderate Storm Damage Removal | $128.30 | $139.33 | $182.43 | NA | NA |
| Slide Removal | $66.15 | $71.84 | $94.06 | NA | NA |

**Potential future annual costs of maintaining the Nantahala National Forest's roads and bridges.**

| Item | Number | Unit Cost | Total Cost |
|---|---|---|---|
| Fixed Cost to Operate | 1 | $60,000 | $60,000 |
| Maintenance of Level 1 Roads | 84.28 miles | $667* | $56,214.76 |
| Maintenance of Level 2 Roads | 863.62 miles | $1397* | $1,206,477.14 |
| Maintenance of Level 3 Roads | 326.19 miles | $5,573* | $1,817,856.87 |
| Maintenance of Level 4 Roads | 63.19 miles | $9,400 | $593,986.00 |
| Maintenance of Level 5 Roads | 54.49 miles | $13,983 | $761,933.67 |
| Inspection of ½ of Bridges each Year | 21 | $350 | $7,350 |
| Replacèment of Deficient Bridges | 1 per year | $223,500 | $223,500 |
| Total Annual Cost | | | $4,727,318.44 |

*Estimates made without considering cooperative management (state mowing, for example) or potential collaborative agreements with partners.

## Appendix F – Comparison of Existing and Suggested Optimal Road System Miles by Maintenance Level

**Existing road system miles by ranger district and maintenance level.**

| | ML 1 | ML 2 | ML 3 | ML 4 | ML 5 |
|---|---|---|---|---|---|
| **Cheaoh** | 71.18 | 203.87 | 56.39 | 24.2 | 4.97 |
| **Nantahala** | 206.65 | 312.04 | 114.02 | 42.52 | 26.54 |
| **Tusquitee** | 82.17 | 109.88 | 96.77 | 35.29 | 5.31 |
| **Forest Totals** | 360 | 625.79 | 267.18 | 102.01 | 36.82 |

(b) (5)

[redacted]

## Appendix G – Chief's Letter of Direction

**File Code:** 2300/2500/7700 **Date:** March 29, 2012

**Subject:** Travel Management, Implementation of 36 CFR, Part 202, Subpart A (36 CFR 212.5(b))

**To:** Regional Foresters, Station Directors, Area Director, IITF Director, Deputy Chiefs and WO Directors

This letter is to reaffirm agency commitment to completing a travel analysis report for Subpart A of the travel management rule by 2015 and update and clarify Agency guidance. This letter replaces the November 10, 2010, letter on the same topic.

The Agency expects to maintain an appropriately sized and environmentally sustainable road system that is responsive to ecological, economic, and social concerns. The national forest road system of the future must continue to provide needed access for recreation and resource management, as well as support watershed restoration and resource protection to sustain healthy ecosystems.

Forest Service regulations at 36 CFR 212.5(b)(1) require the Forest Service to identify the minimum road system needed for safe and efficient travel and for administration, utilization, and protection of National Forest System (NFS) lands. In determining the minimum road system, the responsible official must incorporate a science-based roads analysis at the appropriate scale. Forest Service regulations at 36 CFR 212.5(b)(2) require the Forest Service to identify NFS roads that are no longer needed to meet forest resource management objectives.
Process

Travel analysis requires a process that is dynamic, interdisciplinary, and integrated with all resource areas. With this letter, I am directing the use of the travel analysis process (TAP) described in Forest Service Manual 7712 and Forest Service Handbook (FSH) 7709.55, Chapter 20. The TAP is a science-based process that will inform future travel management decisions. Travel analysis serves as the basis for developing proposed actions, but does not result in decisions. Therefore, travel analysis does not trigger the National Environmental Policy Act (NEPA). The completion of the TAP is an important first step towards the development of the future minimum road system (MRS). All NFS roads, maintenance levels 1-5, must be included in the analysis.

For units that have previously conducted their travel or roads analysis process (RAP), the appropriate line officer should review the prior report to assess the adequacy and the relevance of their analysis as it complies with Subpart A. This analysis will help determine the appropriate scope and scale for any new analysis and can build on previous work. A RAP completed in accordance with publication FS-643, "Roads Analysis: Informing Decisions about Managing the National Forest Transportation System," will also satisfy the roads analysis requirement of Subpart A.

Results from the TAP must be documented in a **travel analysis report**, which shall include:

- A map displaying the roads that can be used to inform the proposed action for identifying the MRS and unneeded roads.
- Information about the analysis as it relates to the criteria found in 36 CFR 212.5(b)(1).

Units should seek to integrate the steps contained in the Watershed Condition Framework (WCF) with the six TAP steps contained in FSH 7709.55, Chapter 20, to eliminate redundancy and ensure an iterative and adaptive approach for both processes. We expect the WCF process and the TAP will complement each other. The intent is for each process to inform the other so that they can be integrated and updated with new information or where conditions change. The travel analysis report described above must be completed by the end of FY 2015.

The next step in identification of the MRS is to use the travel analysis report to develop proposed actions to identify the MRS. These proposed actions generally should be developed at the scale of a $6^{th}$ code sub watershed or larger. Proposed actions and alternatives are subject to environmental analysis under NEPA. Travel analysis should be used to inform the environmental analysis.

The administrative unit must analyze the proposed action and alternatives in terms of whether, per 36 CFR 212.5(b)(1), the resulting road system is needed to:

- Meet resource and other management objectives adopted in the relevant land and resource management plan;
- Meet applicable statutory and regulatory requirements;
- Reflect long-term funding expectations;
- Ensure that the identified system minimizes adverse environmental impacts associated with road construction, reconstruction, decommissioning, and maintenance.

The resulting decision identifies the MRS and unneeded roads for each sub watershed or larger scale. The NEPA analysis for each sub watershed must consider adjacent sub watersheds for connected actions and cumulative effects. The MRS for the administrative unit is complete when the MRS for each sub watershed has been identified, thus satisfying Subpart A. To the extent that the sub watershed NEPA analysis covers specific road decisions, no further NEPA analysis will be needed. To the extent that further smaller-scale, project-specific decisions are needed, more analysis may be required. A flowchart displaying the process for identification of the MRS is enclosed in this letter.

Timing

The travel analysis report **must be completed by the end of FY 2015**. Beyond FY 2015, no Capital Improvement and Maintenance (CMCM) funds may be expended on NFS roads (maintenance levels 1-5) that have not been included in a TAP or RAP.

Leadership

The Washington Office lead for Subpart A is Anne Zimmermann, Director of Watershed, Fish, Wildlife, Air and Rare Plants. Working with her on the Washington Office Steering Team are Jim Bedwell, Director of Recreation, Heritage, and Volunteer Resources, and Emilee Blount, Director of Engineering. I expect the Regions to continue with the similar leadership structures which have been established.

Your leadership and commitment to this component of the travel management rule is important. Together, we will move towards an ecologic, economic, and socially sustainable and responsible national road system of the future.

/S/ JAMES M. PENA (FOR):
LESLIE A. C. WELDON
Deputy Chief, National Forest System

## Appendix H – Southern Region Expectations

**Southern Region Expectations**
**Revised to align with 2012 Chief's Letter**

A. **Background**. During the period 2005 - 2010 the National Forests of the Southern Region successfully completed Sub-Part "B" (Designation of Roads, Trails and Areas for Motor Vehicle Use) Travel Analysis. The result was a set of Motor Vehicle Use Maps (MVUMs) which prescribe the Forest Service roads that allow traffic; and in doing so it also prohibited cross-country travel by off-highway vehicles (OHVs). Forests are now beginning work on Sub-Part "A" (Administration of the Forest Transportation System) Travel Analysis to identify the minimum road system needed for safe and efficient travel and for the protection, management and use of NFS lands; and also to identify roads no longer needed to meet forest resource management objectives.

TAP analysis identifies risks and benefits of individual roads in the system, but especially cumulative effects and affordability of the entire system. Consideration is given to the access needed to support existing Forest Plans, and for informing future Forest Plans and resulting projects. TAP is intended to identify opportunities to assist managers in addressing the unique ecological, economic and social conditions on the national forests and grasslands.

B. **Agency Direction**. Sub-Part "A" Travel Analysis is required by the 2005 Travel Management Rule (36 CFR 212.5). Forest Service Manual 7712 and Forest Service Handbook 7709.55 Chapter 20 provides specific direction, including the requirement to use a six step interdisciplinary, science-based process to ensure that future decisions are based on an adequate consideration of environmental, social and economic impacts of roads. A letter from the Chief of the Forest Service dated March 29, 2012 was issued to replace a November 10, 2010 letter previously issued on the same topic. It reaffirms agency commitment to completing travel analysis reports for Subpart A of the travel management rule by 2015, and also provides additional national direction related to this work, addressing process, timing and leadership expectations. The letter requires documentation of the analysis by a travel analysis report, which includes a map displaying the existing road system and possible unneeded roads. It is intended to inform future proposed actions related to identifying the minimum road system. The TAP process is designed to work in conjunction with other frameworks and processes, the results of which collectively inform and frame future decisions executed under NEPA. These other analyses and procedures include Watershed Analysis Framework and mapping; Recreational Framework planning and analyses; and forest-wide planning under the new Planning Rule. This document (Southern Region Expectations) supplements the national direction for Sub-Part "A" TAPs developed for the Southern Region.

C. **Geographic Scale**. Like smaller scale road analyses (RAPS) that have been underway at the project level, TAPs consider economic, environmental and social effects of roads. Analysis at the smaller project scale, however, does not adequately address cumulative effects and affordability. The Chief's letter requires that proposed NEPA actions be informed by work at the 6th order HUC watershed as a minimum. Southern Region Expectations are for a Unit TAP at the District level or equivalent; and since budgets are generally allocated to the Forest level, District analyses are not considered complete until all other Districts on the same Forest are also complete and have been integrated to create a Forest Scale TAP. As projects which involve travel (road) decisions are subsequently proposed on a unit, additional project level analysis will be required in advance of associated NEPA decisions only if the proposal varies substantially from the Unit Scale TAP covered by it. The purpose would be to show any additional impact on cumulative effects and affordability.

D. **Process**, Review and Approval. Forests Interdisciplinary Teams (IDTs) are expected to conduct analyses, with guidance and review by the Regional Office TAP Review Team (members listed below).

Standard boilerplate, spreadsheets and Executive Summary format will be developed by the Review team for incorporation into the TAP reports. Final review will be by the Forest Supervisor, indicating that the analyses comply with national and regional direction. Upon completion of the last District TAP on a Forest, the Forest Supervisor needs to submit a forest-wide Executive Summary and verify that the cumulative results meet the expectations defined in this guidance.

The Regional TAP Review Team consists of Team Leader Paul Morgan (Engineering), Emanuel Hudson (Biological and Physical Resources), Mary Hughes Frye (Recreation), Paul Arndt (Planning) and various other ad hoc members as needed. They will submit review comments to the TAP Steering Team prior to officially conveying them to the Forest. The Steering Team will be responsible for overall direction and oversight of the process. This team consists of Randy Warbington, TAP Steering Team Lead and Director of Engineering, Dave Schmid, Director of Biological and Physical Resources, Chris Liggett, Director of Planning, and Ann Christensen, Director of Recreation as well as George Bain, Forest Supervisor on the Chattahoochee Oconee NF's and Steve Bekkerus, Regional Legislative Affairs Specialist.

E. **Information Systems**. Analysis will be based upon field-verified spatial data (GIS, or Geographic Information System road and trail layers), and official tabular data (from I-Web, the corporate Forest Service data base) as applicable. ARC Map products will be included as a part of all completed Unit Scale TAPs, and will be provided to the Regional Office TAP review team as a part of the final TAP report.

F. **Access.** As prescribed by 16USC532 the Forest Roads and Trails Act TAPs should identify an adequate system of roads and trails to provide for intensive use, protection, development, and management of National Forest System lands. As such, they should address user safety and environmental impacts, and provide for an optimum balance of access needs and cost. Roads, trails and bridges that are unsafe and where unacceptable risks cannot be eliminated or mitigated due to a lack of funding should be identified for closure or possible decommissioning. Unneeded, temporary and unauthorized routes should be identified for possible decommissioning. TAPs should support current Forest Plan direction and anticipate future Forest Plan analysis needs, as well as Recreational Framework planning and analyses. As unit scale TAPs are completed, associated MVUMs must be reviewed. After appropriate NEPA decisions are made to implement TAP recommendations, future MVUM revisions need to be revised to assure that they are in agreement with those decisions.

G. **Environmental.** One major analysis component of the TAPs is impact of the road system on water quality. In those cases where high road densities on National Forest lands are a major factor in causing watersheds to be at risk or impaired, some roads should be identified for decommissioning in order to reduce the impacts and change the classification. Also, it should be recognized that some existing roads are poorly located and should be eliminated, while some new roads might be needed to replace them and provide essentially equivalent access in better locations, generally farther away from live streams or wetlands. The Watershed Condition Framework should inform each unit's travel analysis. An overriding objective for all roads should be compliance with provisions cited in National Best Management Practices for Water Quality Management on National Forest System Lands, April 2012. While a reduction in maintenance levels may be a desired option for cost reduction, it is not an appropriate strategy when it results in more environmental impacts. Similarly, changes in recreational use should be considered, especially for roads that cannot be maintained to standard and which may begin to attract challenge-oriented four-wheelers that create even further impacts on the environment and on the road.

H. **Financial.** Units should consider all expected sources of funding available to maintain the road system to appropriate standards (based upon 3 year history and current trends), and include all costs that are required to comply with applicable Best Management Practices (BMPs) for their maintenance. Include associated bridge maintenance as well, and replacement costs for those routes which include bridges that are deficient or expected to need major work in the next ten year period. Identify and account for fixed costs (program management, fleet, etc.) when analyzing financial feasibility. Ultimately units must balance costs of maintaining the identified system such that the recommendation will not result in accrual of deferred maintenance on roads and bridges once the TAP is implemented (i.e. there should be a zero balance between anticipated maintenance revenue and anticipated maintenance cost on an annual basis).

The focus of this analysis should not be primarily on disinvestment, i.e. just reducing passenger car roads to high clearance roads in order to meet funding constraints. Roads receiving minimal maintenance have the high likelihood, at least those roads located relatively low in the watershed, of creating additional siltation impacts. They can also have unintended consequences for recreation management. Therefore a better strategy might be to identify roads not required for current operations but which might be needed at some time in the future for seasonal or intermittent closure, or "storage". Other strategies might include scheduling maintenance over a two to three year cycle on less used roads, adding seasonal restrictions, identifying roads to transfer to state or local jurisdiction, and identifying unneeded roads for possible decommissioning. Total mileage of high clearance roads should not generally increase over the amount in the current system unless it is determined that there has been substantial maintenance level "creep" over the years and therefore a substantial increase in high clearance roads is warranted. However it is expected that the number of roads identified to be placed in storage will generally increase from the current level. Finally it should be noted that similar to the road system, the trail system is also over-committed to be managed within its maintenance budget. Therefore, unless maintenance funding is verified to be available over the long-term, it is not acceptable to identify roads for conversion to trails; the more appropriate options would be storage or decommissioning, depending upon future need.

I. **Public Involvement and NEPA** (National Environmental Protection Act) Requirements. Unit scale TAPs are not NEPA decisions; they are analyses intended to inform future projects regarding affordability and cumulative effects. These projects, depending upon specific impacts, will require NEPA decisions prior to implementation. The public must be provided opportunities for comment on TAP recommend-dations near to the time that those actual projects are proposed. This would be expected to include a broad spectrum of participation by citizens, other agencies, and tribal governments as appropriate.

J. **Products**. All final products to be posted on an internal website or on the "O" drive available for access by other Forests and the Regional Office. The final product should consist of the following items:

- A Travel Analysis Report summarizing the process the results of all analyses conducted.
- A map showing the entire Road System, ML 1-5, and delineating potential unneeded roads.
- A list of roads that are proposed for transfer to another jurisdiction and whether acceptance by that jurisdiction is likely within the next three years.
- A tabular summary of issues, benefits and risks for each road in the system. (Although not included in this write-up an example format is available and will be provided to each unit as they begin work.)
- A spreadsheet identifying available maintenance funding and expected costs for applying affordable operational maintenance levels and associated BMPs to the road system to result in a financial strategy that balances funding and costs such that no deferred maintenance will accrue if fully implemented.
- Signature sheets with dates, indicating preparation and review officials, and review by Forest Supervisor.

<u>Attachment 11</u>

Communication from forest silviculturalist Jason Rodrigue

**Timber Calculations Q&A – Questions (from SELC)**

Received as a PDF on 4/30/2020, converted to word on 4/30/2020 and completed for response on 5/8/2020.

(1) On pages B-7 through B-9 of Appendix B of the draft Plan ("Timber Calculations"), there are charts displaying the values for Projected Timber Sale Quantity (PTSQ) and Projected Wood Sale Quantity (PWSQ) for each alternative. Many of the cells contain two numbers separated by a slash, e.g. "2.1 / 3.3."

Are these two numbers the projected figures for Tier 1 and Tier 2, respectively?

USFS Response - Yes, there was an error during publishing. Corrected tables will be added to the website and the final plan.

If so, is the Tier 2 number inclusive of the Tier 1 number, or should the two be added together to calculate the total quantity under both tiers?

USFS Response - The numbers were generated by separate Spectrum models. They should be viewed as independent of each other.

(2)Similarly, pages B-10 through B-14 of Appendix B (which show Tables 5-7), list estimated acreage of different vegetation treatments, by ecozone and tier.

To determine the *total* estimated acreage for an ecozone, is it necessary to add the numbers listed for Tier 1 and Tier 2? Or is Tier 2 inclusive of Tier 1?

USFS Response - Same as second part of Q1, independent.

If the latter is true, then why are some Tier 2 numbers smaller than Tier 1 numbers? For example, "Intermediate treatments" for the dry oak ecozone decrease from Tier 1 to Tier 2 under each alternative.

USFS Response - The model tends to be cyclic in its application of treatments. It appeared to select a higher level of thinning in the dry oak for tier 1 then tier 2. Probably because some of the acres that it would have selected in tier 1 were allocated to regeneration harvest in tier 2.

(3)The Timber Resources section of the DEIS, p. 504, and the Timber Calculations webinar both state that in the Forest Service's analysis of suitability for timber production, some ecozones—including pine-oak, dry oak, and spruce fir—were determined to be economically not compatible with timber production and were therefore eliminated from the suitable base during modeling.

However, the DEIS also notes that between 1,431 and 1,689 acres of spruce-fir forest, between 24,235 and 30,056 acres of dry oak forest, and between 44,850 and 57,961 acres of pine-oak forest would be allocated to MA Group 1 (Matrix and Interface) (*see* DEIS, Tables 30, 40, and 46).

Furthermore, Tables 5 through 7 of the Plan Timber Calculations (Appendix B) estimate that thousands of acres of timber harvests will occur on dry oak and pine-oak forest types under Tier 2 objectives. This is despite acknowledgements in the DEIS that the trees in these ecozones are generally not compatible with commercial timber harvest due to insufficient size and quality.

USFS Response - We want to be able to use timber harvest to manage some of these communities. They represent a good option for regenerating oak and would have our best success with woodland creation in hardwood communities when using timber harvest and fire. As described in the plan the young forest successional class of dry oak likely contains some of the largest sized gaps and young forest openings. There is the need to develop markets where there has been none before and some of our wood products folks have said that markets for low value products are fine in the area surrounding Canton for example. There is also room in the plan objectives to implement some treatments in these forest types as non-commercial though we would want to reserve those for areas where we want that type of work done and do not want to gain road access.  Ultimately it comes down to what we as a collaborative group want to do with treatments like that if there is a way to add value to them then they in turn will create value in outer aspects of our restoration opportunities.

If these ecozones are not compatible with timber production and with commercial timber harvest more generally, then why are such significant portions of them allocated to suitable MAs and why is so much timber harvest estimated to occur there?

USFS Response - We have maintained that our timber production suitable MAs include a mix of both suitable and unsuitable lands. It is not feasible to segregate by management areas all the typically non-productive ecozones, such as dry oak and pine-oak/heath, from other potentially more productive ecozones, such as dry-mesic oak and mesic oak, since the ecozone model typically occur within the same landscape and they all occur across all management areas. Given the departed condition of our forest having these communities near access and areas that can have timber harvest will likely provide us more opportunities to succeed at restoration objectives especially with the dry community types that will likely require timber harvest and prescribed fire both of which are likely to be easier in those timber production suitable management areas.

We disagree with the opinion that this is so much timber harvest. There are several viewpoints on this question. First that one cannot view the dry oak forest type group in the Spectrum model as equivalent to the dry oak ecozone described in the forest plan. The first contains 73,000 acres and the latter contains 49,000 acres. Second, the results go along with the complex and diverse nature of our landscape. The draft Forest Plan contains desired conditions that describe more balanced NRV successional classes. The NRV model describes up to 22% of dry oak ecozone in the young forest successional class. Though Spectrum only provided an estimate of what could happen and what would happen would be guided by the revised plan and the implementation of district level projects, regeneration harvest within the dry oak forest type group for the action alternatives tier 2 vary between 8,000 and 12,000 acres leaving room for prescribed fire to create young forest on the acres of the actual dry oak ecozone.

(4)

The Plan Timber Calculations (Appendix B, Tables 5 through 7) provide estimates for the amount of vegetation management practices that will take place in “white pine and white pine hardwood forest types.” However, it’s not clear what “forest community type” this refers to.

Unlike some of the other “forest community types” listed in Tables 5-7, “white pine” forest types are not an “ecozone” discussed in the Plan and DEIS.

Some of the ecozones listed in Tables 5-7 and discussed in the DEIS have white pine “subtypes”: dry-mesic oak, dry oak, and acidic cove.

The DEIS also discusses removal of white pine in some of the ecozones listed in Tables 5 through 7 of Appendix B: mesic oak forest, dry-mesic oak, dry oak, acidic cove, rich cove, pine-oak heath, and shortleaf pine.

White pine forests are also discussed in the DEIS as a “unique habitat” where they are “presumed to be of natural origin.”

Which of the above occurrences of white pine on the Forests are Tables 5 through 7 referring to as “white pine and white pine hardwood forest types”?

USFS – Response: It appears the main focus of your interest in white pine is the existence of the white pine types only where they are considered natural and desirable. Natural white pine forest is dominated by white pine and typically on steep slopes in steep gorges such as in Linville River or Whitewater River. The use of the white pine types in the draft plan Spectrum modeling represent those ecozones that are in a departed compositional condition. It can become ecologically complicated when looking at subtypes with white pine as a component, but in general white pine would be reduced in those subtypes where it has become much denser than it would naturally occur due to either fire suppression or past land use history. Some oak-white pine subtypes, Mike Schafale in his 4$^{th}$ approximation indicates the subtype needs further investigation into its distinctiveness.

Do the estimated harvests listed under “white pine and white pine hardwood forest” overlap with the harvests of white pine from other ecozones listed in Tables 5-7?

USFS Response - It would be presumed that where an ecozone is currently departed compositionally due to overly abundant white pine it would be restored and transition to another community more closely approximating one of the described ecozones. This acknowledges that there isn’t a white pine ecozone and therefore the vast majority of white pine FTGs that contain white pine as a dominant overstory species when mature would need a level of restoration. That is, if a white pine dominated community was departed because its modeled ecozone was mesic oak, then the restoration work employed should help to guide the community towards the mesic oak overtime. If the modeled ecozone included a subtype that maintained a white pine component the restoration activity would likely include reducing the white pine to more desirable levels and maintenance activities would attempt to keep it there. The Spectrum Model did not make an attempt to transition a harvest white pine FTG to another ecozone but that is what would happen at the district project level. As mentioned during other conversations the draft forest plan is not intended to make site specific decisions.

(5)

Regarding the Backcountry MA, the Plan states at p. 208 that "[f]orest management that enhances or restored community *composition and structure* may occur in this management area to accomplish site-specific restoration goals, although the cutting, sale, or removal of timber in these areas is expected to be infrequent."

Yet the Timber Calculations webinar indicated that under Tier 2 objectives, approximately 25% of all active management would occur in Backcountry.

How much of this active management is expected to be timber harvest?

USFS Response - As modeled in the Spectrum the percentage was small (1 to 2 percent of the active management). As mentioned above, the Spectrum model provides an example of what could happen. District level implementation would guide what does happen and on any give district level project some mix of active management, which includes prescribed fire, and stand improvement work could all occur in the backcountry depending on those site specific conditions.

(6)

Plan standards for Ecological Interest Areas allow for timber harvests under certain conditions, but in some cases it is unclear how the Forest Service will determine whether those conditions have been met.

For example:

Applicable to both EIAs and SIAs, EIA-S-06 states that "Salvaging of dead and dying trees is only allowed if compatible with the biological resource for which the area was established or for public health and safety."

Does this mean that salvages harvests could occur if this is compatible with local biological resources but *not* compatible with public health and safety, and vice versa?

USFS Response - This means that salvaging of dead and dying trees is allowed if compatible with biological needs in the area. It also means salvaging of dead and dying trees is allowed when needed for public health and safety regardless of the biological need.

Where in the administrative record is there listed the "biological resource for which" EIAs are established? They are not listed in the Plan.

Similarly, EIA-S-12 states that "In Ecological Interest Areas, wildlife habitat improvements may be created, maintained, or enlarged if compatible with species for which the area is recognized."

Yet neither individual EIAs nor the “species for which the area is recognized” are listed in the plan. How will the Forest Service make this determination?

USFS Response - We agree that each EIA does not have individual biological resources listed; these standards developed from having a combined management area for EIA and SIAs. Thank you for pointing out that more clarification about this is needed at final.

(7)

The estimated timber harvests for the spruce fir ecozone in Tables 5-7 of Appendix B list only “balanced and irregular uneven-aged regeneration harvests.” However, the DEIS (at p. 170) notes that treatments in the spruce-fir ecozone would include “[t]hinning and release, various uneven-aged and limited even-aged treatments.”

Why is there a discrepancy between the Plan’s estimations and the DEIS’s analysis of vegetation management in this ecozone?

USFS Response - The table 5 only shows what was scheduled using Spectrum. It would be our intent to include some of the other treatments listed in the DEIS for the benefit of restoring conditions in the spruce fir ecozone. The presence or absence of treatments from table 5 -7 does not preclude them from being selected as a desired treatment on a site specific project. We used Spectrum to generate reasonable estimates of a planned timber sale program, but did not constrain the model to produce every possible combination of treatments. We are actually working currently with ATC to plan and implement non-commercial thinning treatments in red spruce.

Tables 5 – 7 are intended to comply with FS Handbook 1909.12Chapter 60 Section 65.1: Display of Forest Vegetation Management Activities. This section explains them as a “display of planned types of vegetation management activities including the planned timber sale program and the proportion of probable methods of timber harvest”. We used an average of the amount of management actions for 2 planning periods in Spectrum as a reasonable estimate, but not every combination of management actions and vegetation types were constrained in the model These estimated practices are not a commitment to take action or a proposal for such action and as such presence or absence of an activity from the tables is not an indication of future use or non-use. We intend to supplement the introduction to tables 5-7 with the recognition that the practices displayed are possible and probable but not every management action and vegetation type combination is identified.

(8)

The Forest Service’s determination of “Acres Likely to be Commercially Viable within MAs That Allow Timber Harvest,” presented in Table 2 of the timber “operability” analysis, indicates that Alternative C has around 235,000 “viable” acres whereas Alternative B and D have 265,000 and 260,000 acres, respectively.

It is appears that the Forest Service’s calculation of commercially viable acres for Alternative B includes 13,200 acres within the old growth patch networks for that alternative, but that acres within the old growth patch network are not similarly included for Alternatives C and D.

Is this accurate? If so, is this an error?

USFS Response - We plan to check on the old growth layers used in the analysis and check to make sure the Erase feature in Arc map worked properly. If there is old growth that was selected for inclusion in the old growth for that alternative by us in the calculation then it will need to be adjusted.

(9)The Timber Calculations webinar indicates that under Tier 2, only 2% of timber harvests are from management areas that are not suitable for timber production. Yet the Plan Timber Calculations in Appendix B estimate more than 10,000 acres of timber harvest under Tier 2 objectives for the dry-oak ecozone, and additional harvested acres on the pine-oak heath ecozone—both of which were deemed “unsuitable” for timber production during the agency’s suitability analysis.

Not including these two ecozones as suitable makes it difficult to understand how these areas will be managed in various alternatives and tiers. They are clearly the focus of substantial timber harvest even though they are considered unsuitable ecozones. For other unsuitable categories (e.g. riparian and steep slopes, there are Plan components that help the public understand how decisions for these areas will be made in the Plan and under different tiers. These ecozones considered unsuitable for timber production are actually some of the ones where there is the most agreement on doing ecological restoration. However, there seems to be nothing in the DEIS or Plan that ties timber management in these ecozones to ecological restoration nor identifies how timber harvest would be guided. Is there any information in the Plan and DEIS on how timber harvest in these ecozones would be guided?

USFS – Response: The intent for management in these areas is to move closer to the desired conditions in the ecozones section through management of timber and fire in certain areas while leaving other areas to move towards late structural classes. The plan direction is primarily in terrestrial ecosystems section of the plan. Timber management would be guided by the forestwide plan direction for timber management. The intent was to use the departure from NRV successional classes as a guide. There are desired conditions that describe future seral class levels. District level projects would assess whether site specific occurrences of the dry oak ecozone (for example) are appropriate for restoration treatments (see ECO-DC-10). The dry oak ecozones have the greatest amount of woodland within their desired conditions. These woodlands could be created across multiple locations across the forest where access is not limited.

Attachment 12

Forest Service Deep Dive Q and A – Timber Calculations (May 1, 2020)

**Forest Service Deep Dive Q and A – Timber Calculations**
**May 1, 2020**

**Q: Regarding estimated acres of land for timber management (commercially viable currently) - why is the range between upper and lower limits so large? Which management areas are included?**

**A**: Estimated acres of land operable for timber management is described in Appendix B on p. B-3. The range represents what could be accessed with the current road system (low #) versus what could be accessed with new road construction (high #), based on FSVeg and what is likely to be commercially viable in the next 10 to 20 years.

Management Areas that allow for timber harvest are Matrix, Interface, Backcountry, EIAs, SIAs, Administrative Sites, Experimental Forests, AT corridor, National Scenic Byways, Heritage Corridors, Wild and Scenic Rivers, Roan Mountain, Cradle of Forestry. In many of these management areas, timber harvest is confined to specific purposes as defined in management area direction.

We updated the operable land calculations for Alternative B in May 2020. The Feb 2020 calculations of available acres for this alternative appeared to contain several pieces of designated old growth. These were removed and new shapefiles produced. They are published on our website.

**Q: When it comes to implementation, what additional resources does the FS need in order to move toward tier 2 timber goals? Without those additional resources ($), what sort of collaborative work can be done to aid in reaching those goals. More basically, what help does the FS need to get to tier 2, or even tier 1 for that matter? How can industry folks or private citizens help develop harvest plans or help put together timber sales on the forest? If industry folks or private citizens can't help, who can? NGOs? How?**

**A**: This is a broader topic than the timber analysis and part of the answer will come through conversation with stakeholders and partners. Though having this answer now would aid in comments regarding the tiers of the draft plan, this questions also speaks to the implementation phase. Some tools for bringing in more capacity include the Good Neighbor Authority through which the NC Forest Service can contribute resources, such as inventory of stand conditions in the current Lickstone Project on the Pisgah Ranger District. The Nature Conservancy has also helped with inventory work in projects under the Collaborative Forest Landscape Restoration project on the Grandfather Ranger District. Additionally, taking an all lands approach that crosses national forest boundaries could also add efficiencies.

**Q: How many acres of site index of 80 or more are found in the Matrix management area? And how many have been regenerated since the 1960s? How about for the Interface management area?**

**A**: Please see the table (acres are estimates):

| | **Alt B** | | | **Alt C** | | | **Alt C** | | |
|---|---|---|---|---|---|---|---|---|---|
| | NAN | PSG | Total | NAN | PSG | Total | NAN | PSG | Total |
| Matrix/age<55 | 61,164 | 36,049 | 97,213 | 51,948 | 30,512 | 82,460 | 62,487 | 35,627 | 98,114 |
| Matrix/SI>80 | 155,178 | 102,710 | 257,888 | 125,917 | 78,477 | 204,394 | 157,096 | 100,842 | 257,938 |
| Interface/age<55 | 4,410 | 5,829 | 10,239 | 3,969 | 5,284 | 9,253 | 4,409 | 5,792 | 10,201 |
| Interface/SI>80 | 14,350 | 15,505 | 29,855 | 11,946 | 12,415 | 24,361 | 14,356 | 15,416 | 29,772 |

**Q: Why does the species/product mix vary so much with alternatives for forest products? Considering the proposed acreages for timber harvest are so similar, where are those differences coming from?**
**A**: Our interpretation of the variation is that it occurs between Alternative A and the action alternatives and then again between Tier 1 and Tier 2 of the action alternatives. We agree that the objectives are similar across all alternatives. The differences come from the FVS vegetation model and the Spectrum model. For Alterative A we used historical sale information to connect actual product mixes to sale acres for different treatments and then used GIS to connect these numbers to management areas and geographic areas. This allowed the Alternative A Spectrum model to closely approximate what has been done on the forest in recent years. For the action alternatives, there was an increase in the proposed harvest levels, these new harvest levels would be implemented under a restoration focused management plan that used the Natural Range of Variation to guide early age class creation in a variety of ecozones, ones that may not have been prioritized for harvest under the current plan. These approximations resulted in an increase in the harvest in the intermediate and dry oak types and a decrease in the harvest in the even aged harvest in the cove types. This is all in Tier 1. Under Tier 2 objectives, with the increase in the harvest acres we anticipate increased harvest in cove ecozones. This along with the increase in overall harvest levels drove the species mix proportions back to ratios more closely approximating Alternative A, albeit at higher harvest levels overall. There are also some changes in management area allocation that occurs across alternatives but given the size of the forest changes in management area allocations, this is likely a lower level contributor to the product mixes estimated in the DEIS.

**Q: Can we have a map of the operable base as well as the commercially viable base?**
**A**: These layers are now available on the forest plan revision website. Go to https://www.fs.usda.gov/detail/nfsnc/home/?cid=FSEPRD709554, scroll down towards bottom for spatial data links and the operability and suitability data will be there. An important caveat with this dataset is that the operability maps were designed for land management planning analysis only and does not take the place of project specific analysis. This dataset is not expected to be directly used for project level planning.

**Q: What is the sustained yield for the operable base?**
**A**: This was not calculated. Sustained yield was calculated for the potentially suitable base as required by the 2012 Planning Rule. This totals 45 million cubic feet based on roughly 700,000 acres and shows the high level yield limits and is not meant to be a target or objective. We did not constrain the Spectrum model for vegetation treatments only on the operable base, and therefore, have not calculated a long term sustained yield on only that portion of the forests. However, the current plan analysis based the Allowable Sale Quantity on active management on about 276,000 acres, which approximates the amounts in the operable base (Nantahala and Pisgah Forest Plan Amendment Five, E-7).

**Q: Could you please clarify whether Tables 5-7 in the Appendix B (Timber Calculations) if Tier 2 includes acres treated in Tier 1 (cumulative) or if its additional stand-alone acres?**
**A**: For each alternative and for each tier a separate SPECTRUM model was built and run. The outputs that are presented in the tables are the model outputs based on the objectives and management area allocations for that alternative and tier. If an alternative and Tier was selected then we would work towards those objectives (Tier) and the numbers presented for that tier are estimates of what the outputs would be (i.e. you would not add tier 1 to tier 2 for a given alternative).

**Q: On the table on p. 80 of the consolidated objectives, the reforestation acres generally match up with the acres for regeneration and intermediate harvests. Do those acres account for natural reforestation or are those artificially reforested acres or both?**
**A**: It is combined natural and artificial reforestation, including actions to improve composition in an area. A lot of the work on the Nantahala and Pisgah NFs historically is natural reforestation. Depending on seed produced by the canopy and other factors, some areas are better suited for natural or artificial reforestation, but it is primarily natural reforestation in western NC. But if we're engaging in more restoration, and if restoration is looking at changes in composition of what is currently growing to community types that are more appropriate for that site ecologically or in the context of climate change, there may be an increase in the amount of acres for artificial reforestation and actions to improve composition and structure.

For the reforestation, in most cases in western NC, a harvested stand will regenerate to a young forest naturally that fully occupies the site at the time of canopy closure. On Nantahala and Pisgah NFs lands, most regenerated stands require some level of site preparation to begin the process of guiding species composition towards desired conditions. At the early stages of stand development treatments may include reducing stump sprouts of undesirable species or removing low shade from non-merchantable and undesirable midstory trees that remained after the regeneration harvest. Under the new forest plan many of the “undesirable” species removed or reduced would be those that do not fit in with what the natural range of variation calls for on the site or those that will have a lower chance of survival in the long-term under a changing climate. A percentage of the sites regenerated might also receive tree planting. When tree planting is included in a regeneration sequence, site preparation assumes the additional burden of ensuring that planted investment are maintained and survive to contribute to the stand composition in the future. Examples of this might include planting shortleaf pine in a recently harvested white pine plantation or adding cluster planting of mesic hardwoods to group selection harvests in a cove. All of these examples and more would contribute to the acres in table 10.

**Q: Objective ECO-O-4: to restore 1,500- 4,000 acres over 10 years under tier 1 seems low compared to the desired condition for open woodlands is 360-480,000. While reaching this DC maybe the most difficult of all the structural conditions to achieve and will take multiple planning cycles to move towards, 1,500-4,000 acres barely puts a dent in that if a dent at all. Especially if you consider using**

**fire and timber harvest as the two main drivers to get there. I think many were hoping for at least that number annually as opposed to over the 10-year timeframe.**

**A**: It is going to take work and time to get woodlands established. Because of this, movement towards desired conditions will be a ramping up effect, getting conditions started in that direction but not necessarily getting to fully restored woodlands over the planning period. It will likely take multiple burns over decades to get to the maintenance phase for woodlands, and the numbers in the objective indicate the number of acres anticipated to be in the maintenance phase even while there may be a lot more acres moving that direction. Based on experience at Buck Creek serpentine woodlands, it will require multiple burns to restore the understory. In some places it took 15 years to restore the habitat.

**Q: Can commercial treatments potentially be included in the stand improvement category or if those are considered all non-commercial treatments. Specifically, I'm thinking about uneven-aged harvests (single entry thinnings) directed to develop open forest/ woodland structure. Would all those types of harvests fall into the regeneration and intermediate thinning categories or could those contribute to the stand Improvement acres?**

**A**: Stand improvement acres are much higher than regeneration or thinning. For the stand improvement, those acres were set after internal discussion regarding additional treatments that may need to be complete on the landscape in areas that may not have access or be in areas where we would not want to build access. Several examples may include release treatments around red spruce, noncommercial slash down treatments in the backcountry, or noncommercial thinning to create woodland structure in stands of timber with low commercial value. It was assumed that these types of treatments would need to occur and be above the normal stand improvement treatments that occur within our commercially treated stands. Additionally, it was determined that there may be a need to increase the frequency of entry into regenerated stands in order to meet the Plan's desired conditions regarding compositional restoration. This may include additional entries in stands that typically require those treatments or adding those treatments to stands that may not have received a stand improvement treatment in the past. All of these activities that might not result in a commercial product are included in the numbers and could fall into stand improvement.

Generally speaking, stand improvement is a prescription applied to stands that are even-aged or multi-aged where the size of the trees being cut are not merchantable in size. This would commonly occur in the regenerated portions of the stands as they begin to close canopy. For group selection this would occur in the young gaps, in two-age treatments it would be in the large open areas, etc. Even with the above portions of the answer, there would still be opportunities to expand how we used the stand improvement treatment. Some of these expanded treatment options could produce some commercial sized products especially since our forests are aging and we are regenerating so few of them. Whether they were actually removed as a product is another question. For example, doing stand improvement in northern hardwood/spruce fir ecozone ecotone is likely to result in merchantable sized trees, but if we were in norther flying squirrel/spruce-fir moss spider habitat it is likely that we would not remove trees. If we did a stand improvement in a dry oak community to create a woodland, we might cut merchantable trees but they would likely not be desirable for a timber purchaser (other than firewood). Other places where we could mix stand improvement and woodland creation includes where we are burning. Burning alone does not create a good woodland structure but if we burn several times and then apply stand improvement treatments to improve the stand structure, that would likely not result in commercial products. Incidentally, the Spectrum model includes a thinning and burn prescription that is used across all alternatives, albeit maybe at a lower degree then desired, that was designed to go after creating woodland structure. The model also includes a significant number of burning acres that was intended to open up the forests where it was applied by itself. In table 10, we inflated the stand improvement numbers above what equates to the sum of the thinning and regeneration harvests to account for repeated stand improvement entries on young forest areas  to better manage composition as they transition into mid seral classes but also to address those treatments that were in areas that would not result in a commercial harvest (due to MA direction, remoteness, or non-merchantability, etc). Some of those acres could certainly be used to generate woodland structure.

**Q: The FS is predicting an increased volume of low-quality hardwoods and pine to be harvested, how do you plan on achieving this when demand for those products is so low? With so much low quality/value timber, how will you avoid projects that result in no-sale? How will you take into consideration local markets/industry needs when designing projects?**
**A**: The answer to this question varies regionally. In some places around the Canton Mill, for example, there may be a market for low quality hardwoods. It will be important to work together to try to add value to those products when possible, and at the district level there could be strategic packaging of timber sale units that include both higher and lower quality products. The mix of stands as well as expense of road maintenance and other issues are all put together to appraise the sale value. This question also gets at the larger understanding that "we" the FS and its partners need to develop surrounding a land management plan that includes timber harvest for restoration objectives and wildlife benefits.

**Q: If we find out through monitoring that we are meeting woodland objectives through fire and we are moving towards desired conditions faster than expected, does it become a problem to overshoot the woodlands objective?**
**A**: The objectives generally are a snapshot or tactic to achieve desired conditions, but they are not considered caps or constraints on management, which are found in the standards and guidelines. The objectives should be seen as a guidepost on the way towards desired conditions. Objectives could be exceeded when there is a need to increase the pace and scale toward achieving desired conditions, and only if, no other plan components would be compromised with the expansion of those objectives.

**Q: I'm a bit confused with the notion that the Forest Service can overshoot the objectives in the Forest Plan without a plan amendment. Can you explain why exceeding some objectives might create problems for an "integrated" plan? Or for your effects analysis and other legal requirements?**
A. The planning team has been innovative in creating Tier 1 and 2 objectives where Tier 1 are the objectives required by the 2012 Planning Rule that are fiscally constrained, but there is no guidance on Tier 2 objectives. Typically, objectives can be exceeded as long as other plan components continue to be achieved. However, any project or activity on the ground must demonstrate consistency with the plan's desired conditions, standards, and guidelines, and if plan components conflict, a plan amendment could be needed. It is the role of the environmental analysis to evaluate how proposed management relates to effects on multiple resources areas. See the answer above for more information.

**Q: Are there are no numerical caps in the plan?**
**A**:  The sustained yield limit of 45 MMCF may be viewed as a limit. Other limitations on projects are captured in plan standards. Some standards have numerical requirements, such as "within 100 feet of perennial springs, bogs and other wetlands" (SZ-S-01). The standards regarding silviculture and timber management have specific numerical constraints. Other standards restrict certain project activities from occurring. Guidelines may also have numerical requirements on project activities.

**Q: If the average production has been about 1.7mmcf/yr what has to happen to reach about 3.8 in Tier 1 of alternatives B, C, and D?**
**A**: Reaching Tier 1 requires that we are productive in the use of current resources and bring in more resources to our projects, including through collaboration with partners for resources and community support. Efficient NEPA will be a part of reaching these goals, as will prepping and advertising sales and creating a reasonable market for those sales. The issue is larger for the jump from Tier 1 to Tier 2. Much of Tier 2 would require partners to have a collaborative understanding of the program and would depend on resources contributed by partners to reach those goals.

**Q: Have you taken into account all the sawmills that have gone out of business? How to get work done when so many mills are out of business? To stay in business, mills need a steady flow of projects. Start/stop is not economical.**
**A**: The last five or six years have been tough on the wood products industry for many reasons. The economic conditions that affect the timber industry are beyond the control of the agency. However, we can collaborate with other federal, state, local agencies as well as adjacent landowners to help build the markets needed to meet the needs of all our stakeholders. If restoration work can be done consistently (the planned district projects flow through the NEPA process smoothly) and with a steady flow of certain types of products, there is the possibility for working together and for businesses to adapt or grow. Having diverse collaborative groups engaged in project planning will facilitate an understanding of restoration opportunities and the outputs that are possible.

**Q: Under Table 1 of Appendix B, lands not suited for timber production due to technical or legal reasons, there is no entry for alternatives B, C, and D. Rows D and E show totals based on suitability because timber production is compatible with desired conditions and objectives - or not compatible. But what is compatibility defined as? Are you referring to compatibility only to what's written in the plan or is this a consideration of project level factors like steepness of slopes, exclusion for archeological sites, etc.**
**A**: For Table 1, the values for Alternatives B, C, and D are the same as Alternative A for the first three rows.
Compatibility with timber is defined in Chapter 60 of the 2012 Planning Rule and the management intent for different areas (FSH 1909.12 Ch. 61.2). Matrix and Interface management areas are compatible with timber production as a primary or secondary use of land, and other MAs are not. Within Matrix and Interface management areas, there are parts of the landscape that are not suitable for timber production including riparian areas, critical habitat, and designated old growth.

**Q: What (and where) are the other trade-offs between operable/viable acres and designations across alternatives? Does the decreased operable and viable acreage in alternative C directly relate to the larger designated old growth network?**
**A**: The variability in operable acreage across alternatives is largely due to differences in backcountry, matrix, and interface management area allocations. The current road system does not change by alternative (physically). The distances that equipment can harvest also do not change, leaving the management areas as the primary driver of differences. Alternative C has more backcountry, as well as EIA acres, so that plays a larger a factor in the operability calculation than the designated old growth network.

**Q: How does the order of entry change across the different alternatives?**
**A**: Order of entry is a concept that sits more on the implementation side of the forest plan. It is anticipated that the forest and each district will need to evaluate the forest plan management area assignments for their district, the objectives of the plan, the most pressing needs for restoration and habitat, and partner's interests on the surrounding landscape. They would then need to decide the best strategy for implementing the revised plan and how their district projects would look. Implementation could take many forms. Examples include larger landscape project areas that address many needs in the same area at once (Twelve Mile Project for example) or restoration focused projects like those that have developed most recently on the Grandfather Ranger District.

The order of entry concept arose during the forest service era when timber production was a large goal within the Forest Service, in many arenas these two concepts have remained paired (unfortunate). The order of entry concept is actually very beneficial for restoration and can be utilized to ensure that the majority of a district's lands are examined for needs over the full planning horizon and that certain parts of the district are not overlooked or neglected allowing problems worsen.

**Q: I am interested in seeing reports referred to in the DEIS, especially Lewis et al, 2017 and the process paper for NRV analysis. Is there any process paper specifically on the use of the Spectrum model?**
**A**: The Lewis et al and process paper for NRV referenced in this question have been posted on our website. Appendix D of the DEIS was meant to serve as a process paper for the Spectrum model.

**Q: During building the Spectrum Model was there too much acidic cove assigned to the white pine forest type groups?**
**A**: There are several factors involved in answering this question: The crosswalk between USDA Forest Types (EV Code) and Ecozones started in 2012 when the Forest set up a meeting with several research (Southern Research Station) and state agencies including the NC Natural Heritage Program to discuss how to best connect the two community classifications. The most noted result of the meeting was the consensus that there was significant overlap and a lack of a one to one relationship between EV code and ecozone. The results of this 2012 meeting were the starting point for the 2014 FVS analysis that attempted to link FIA forest type groups (FTG) to FSVeg forest types and ecozones. During this effort the crosswalk was expanded using the examples and estimates typified from the 2012 meeting results. Each FIA plot used was assigned an ecozone value based on the 3rd approximation of the ecozone model. Each plot was assigned a forest type group code based on the FIA plot data. Based on the results, out of the 211 FIA plots that were identified in the acidic cove ecozone 26 (12%) were assigned a white pine/ white pine hardwood FTG which could have included the hemlock FTG based on the crosswalk. It is assumed that there would be a subset of the 26 plots that were typed as the hemlock FTG based on the plot data. Of those 26 plots: 8 were EWP (103), 2 plots were EWP/EH (104), 3 plots were EH (105), and 13 plots were EWP/NRO/WA (401).

When the Spectrum analysis units were built for each alternative, each stand's EV code was assigned to a FTG from the FVS work in order to help link an FVS yield profile within the model. Again the same crosswalk was used. Based on GIS outputs we estimate that roughly 10% of the white pine and white pine hardwood FTGs in the Spectrum dataset were originally a Hemlock (05) or hemlock hardwood (08). When the cove hardwood-white pine-hemlock forest type (41) is included the percent increases to 29% but the 41 could include a significant amount of white pine and hardwood owing to the fact that hemlock trees have been in such a decline over the last decade due to hemlock woolly adelgid. As is the case with all the EV codes in the NFsNC FSVeg dataset, they were likely assigned earlier then the onset of Hemlock Woolly Adelgid. As a final discussion point, it was important for the best estimate of the current conditions to be the starting point of the Spectrum model for each alternative. This included attempting to portray those situations where white pine has become more aggressive on the landscape and we felt that in the case of acidic coves given the presence of white pine as a minor component and with the legacy of HWA that these sites (along with dry oak types) are the best locations to expect a departed compositional condition related to increased white pine presence.

**Q: How was Tier 2 for young forest and mechanical harvest calculated?**
**A**: The upper end on the Tier 2 for young forest was influenced by the acres in the current forest plan EIS. We did not want to exceed what was planned in the current plan, because it has not been able to be accomplished, so exceeding the expected mechanical treatment in the current plan wouldn't be realistic. For that upper end for mechanical harvest, there is a typo in a Chapter 2 table that refers to the upper end as 3,600 acres, but it's actually 3,800 acres in the plan and analysis, which equates to 3,200 acre of regeneration harvest and 600 acres of intermediate thinnings.

**Q: I want to understand better how the species and rare habitat analysis is dependent on and built around the Spectrum model. It's fairly clear in the DEIS that species analysis is dependent on Spectrum because the ESE model seems to take outputs from Spectrum (e.g. young forest; old growth) to gauge effects on different species groups. What are the mechanics of using the Spectrum outputs in the ESE model? Is ESE dependent in any way on the NRV model? What are any explicit or implicit assumptions around the Spectrum and NRV models relating to species analysis?**
**A**: The rare habitat analysis did not use Spectrum outputs. Spectrum modeled the objectives in the plan. The plan objectives took into account the Natural Range of Variation. Outputs from the Spectrum model from each alternative are in an excel file format. They are able to be sorted by the outputs identified in Appendix D of the EIS. Successional classes of forest type groups were estimated in Spectrum. However, there is not an exact match of forest type groups to Ecozones, especially since we do not have a current inventory of ecozones. An estimate of forest type to ecozones was made as a first approximation of the successional classes, and these were adjusted in the ESE model based on professional judgement. Successional classes that were studied included young forest, woodlands, and old growth. ESE rating scores by individual ecozones were based on the NRV model and reflective of balanced successional classes for the highest rating. For any individual successional class, if the percentage exceeded or did not meet the desired NRV range, ratings were adjusted. For some ecozones that exceeded either old growth or young forest, ratings were downgraded.