STUDY PLAN

A National Study of the Consequences of Fire and Fire Surrogate Treatments – Southern Appalachian Mountains

SRS-4104-2008-2

Prepared by:

____
Thomas A. Waldrop, Research Forester

Approved by:

____
John A. Stanturf, Project Leader

STUDY PLAN

A National Study of the Consequences of Fire and Fire Surrogate Treatments – Southern Appalachian Mountains

This study plan outlines local procedures for the national study on fire and fire surrogate treatments (FFS), funded by the Joint Fire Sciences Program and the National Fire Plan. The Southern Appalachian Mountain site is one of thirteen sites across the United States where similar treatments and measurements will be installed. Protocols for each variable were established by the Science Management Integration Committee (SMIC) of the FFS. Variances to the national protocols will be highlighted here.

GENERAL LOCATION

Three study sites (blocks) were selected on the Green River Game Land in Polk County, NC. This forest is managed by the North Carolina Wildlife Resources Commission and is near Asheville, NC (figure 1). Statewide, some 2,000,000 acres of public and private lands are managed by the Wildlife Resources Commission for public hunting, trapping and fishing, and are designated collectively as Game Lands. The North Carolina Wildlife Resources Commission sponsors many programs that promote conservation and wise use of the state's abundant natural resources, and provides assistance for landowners wishing to manage wildlife on their lands. The Green River Game Land covers 5,841 hectares of forests and wildlife openings. Land within the county can be classified as either mountain or piedmont. The Game Land is entirely with the mountain region.

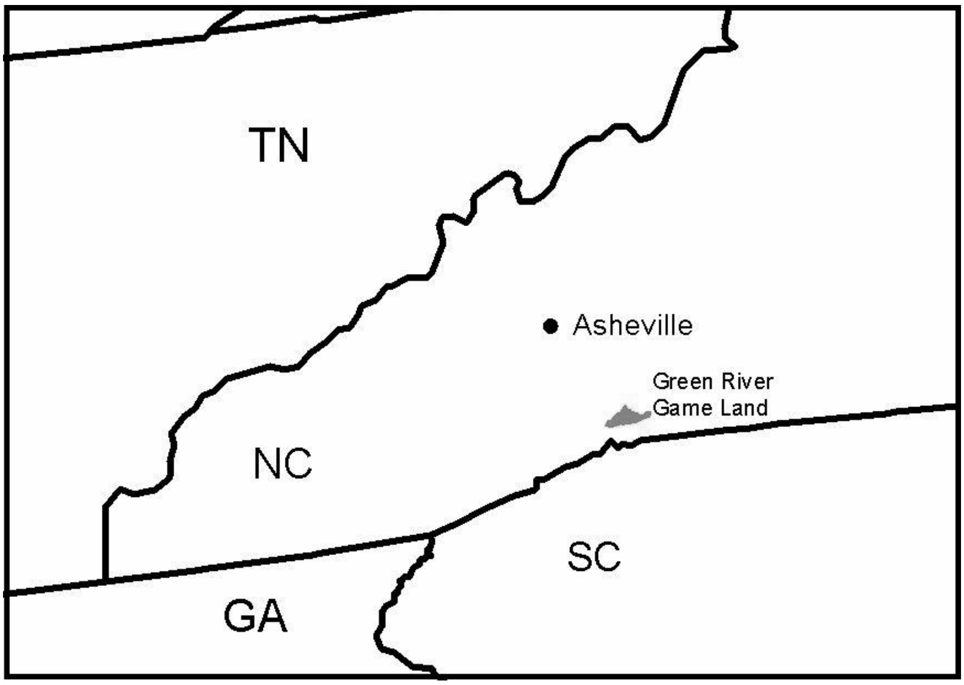

Figure 1. Approximate location of the Green River Game Land.

The Green River Game Land contains several large blocks but outholdings of private land dissect other portions of the area (figure 2). A wide variety of cover and site types can be found on the Green River Game Land because of its diverse topography. Agriculture is a growing industry in Polk County but little evidence of past farming is seen on the Game Land. Most stands are comprised of mixtures of hickories with xeric oaks or mesic oaks depending on topographic position. Shortleaf (*Pinus echinata*) and Virginia (*P. virginiana*) pines are found on ridgetops while white pine (*P. strobus*) is found in moist coves.

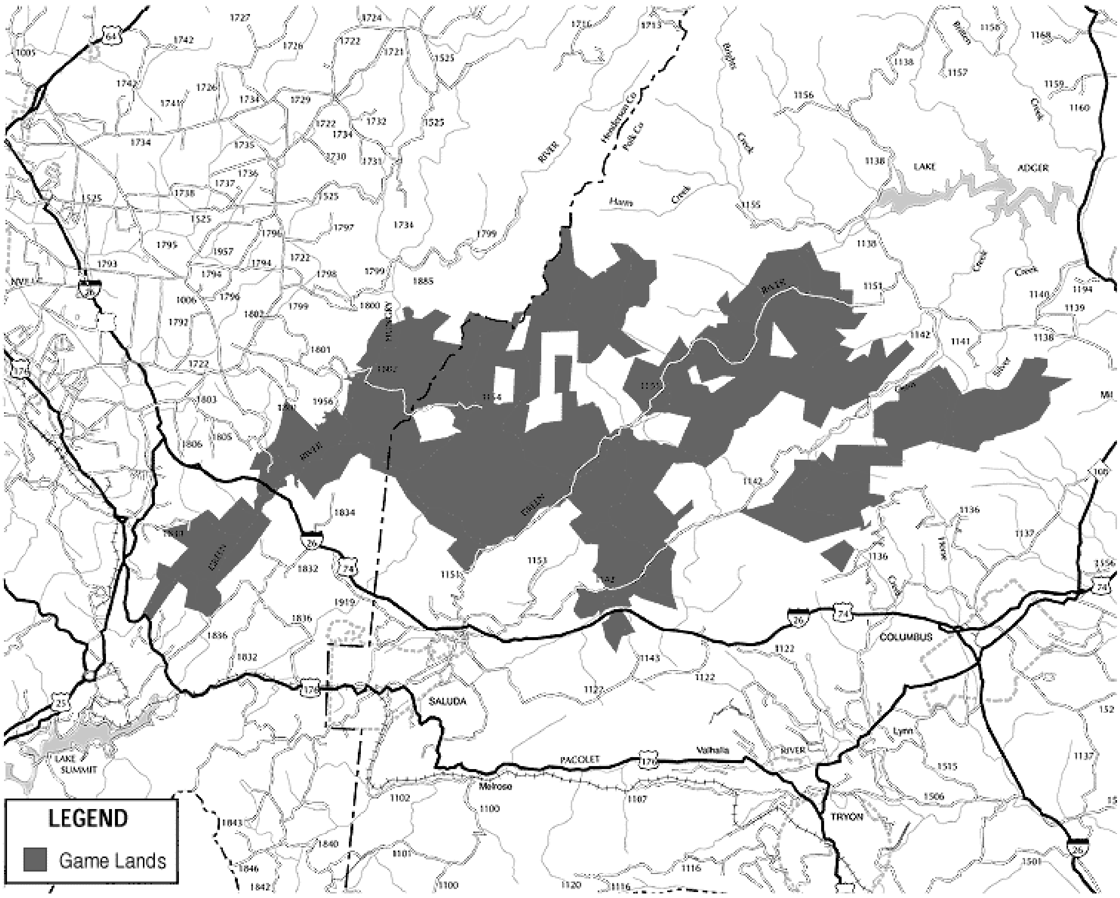

Figure 2. The Green River Game Land.

Most soils on all study areas are of the Evard series (file-loamy, oxidic, mesic, Typic Hapludults). These soils are described as very deep and well drained in mountain uplands (USDA Natural Resources Conservation Service 1998). They were formed in residuum and material deposited by soil creep that weathered mainly from high-grade metamorphic rock, such as biotite gneiss. Three subclasses of this complex are distinguished by slope: 15 to 30, 30 to 50, and 50 to 85 percent. All three subclasses are present in study plots.

Portions of two replications (blocks 1 and 2) have soils of the Cliffield series (loamy-skeletal, mixed, mesic, Typic Hapludults). These areas are described as moderately deep, well drained, mountain uplands (USDA Natural Resources Conservation Service 1998). The soils are formed of residuum and material deposited by soil creep mainly from high-grade metamorphic rock, such as sillimanite-mica schist. These soils are very rocky and are found on slopes of 15 to 30 percent.

STUDY SITES

Twelve study sites, one for each treatment area, were selected on the basis of size, stand age, cover type and management history. Each site had to be a minimum of 14 hectares to allow for a 10-hectare measurement area and a buffer of at least one tree length (approximately 20 m) around the measurement area. Selected sites were judged to be in danger of uncharacteristically severe wildfire due to heavy fuel loads. None had been thinned during the past 10 years and none had been burned (wild or prescribed) in at least 5 years. Stand ages varied from 80 to 120 years. Oaks dominated all sites including northern red oak (*Quercus rubra*), chestnut oak (*Q. prinus*), white oak (Q. alba), and black oak (Q. velutina). Other dominant species include pignut hickory (*Carya glabra*), mockernut hickory (*C. tomentosa*) and shortleaf pine. A thick shrub layer occurred on approximately one-half of the study area. Predominant shrubs include mountain laurel (*Kalmia latifolia*) and rhododendron (*Rhododendron maximum*).

Selected study sites are in three blocks on the Green River Game Land. Blocks 1 and 2 are in adjacent areas but separated by Pulliam Creek. Block three is approximately 2.9 kilometers to the southeast of blocks one and two and across the Green River (Figure 3). Within each block, four separate treatment areas were identified and randomly assigned to one of four treatments: control, prescribed burn, mechanical fuel reduction, and prescribed fire pus mechanical reduction. In figure 3, areas to be burned are outlined by black lines representing fire lines. Purple lines outline areas designated for mechanical fuel reduction. Areas that will be have both treatments are bordered both black and purple lines.

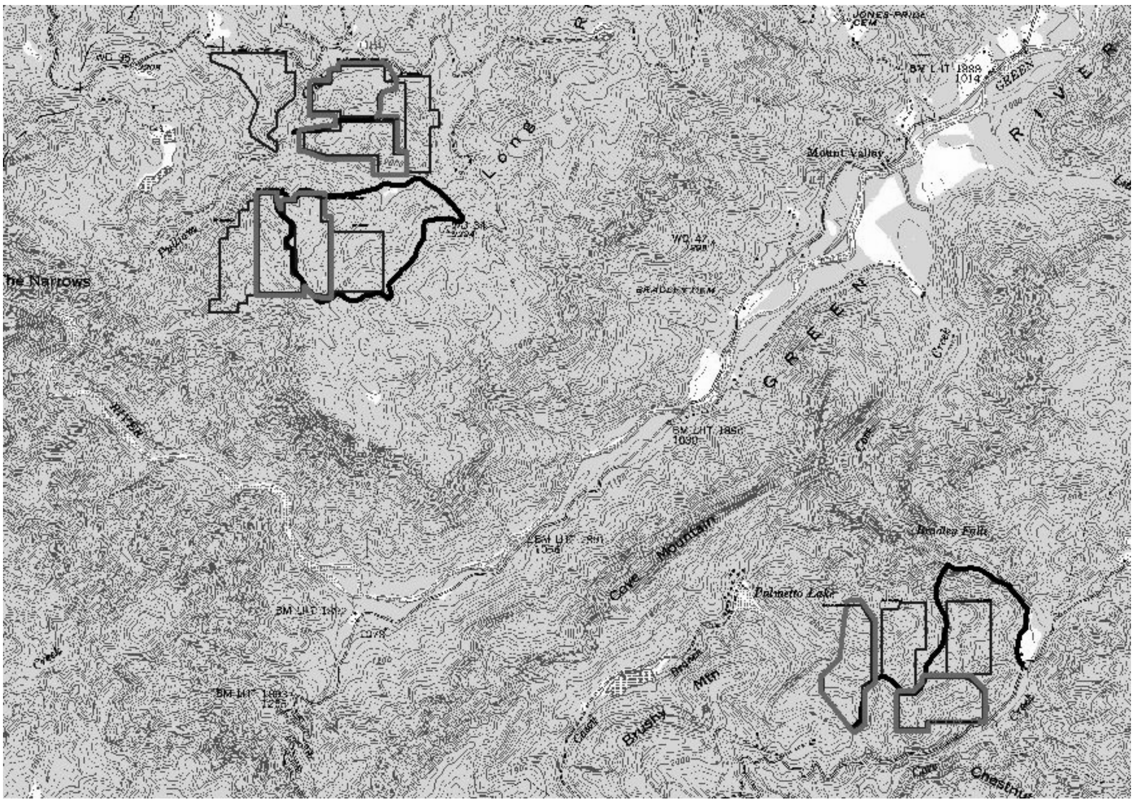

Figure 3. Study plot locations on the Green River Game Land.

Within each treatment area, permanent grid points were established on a 50-m spacing following cardinal directions. Grid point locations were determined randomly using ArcView GIS software. Points were drawn at the appropriate scale over topographic maps of each treatment area. Using printouts of these images, one grid point was located on the ground using readily identifiable ground objects as a reference point. All other grid points were established using a compass and hypsometer to measure from the first point. The hypsometer measured distances and adjusted for slope. Each grid point was marked with a 1-m long rebar driven approximately 30 cm into the ground. The rebar and several trees facing it were marked with bright pink paint. All grid points were tagged with a numbered aluminum tag. Numbering began with the northeastern corner and followed a zig-zag pattern traveling east and west on alternate rows. A total of 36 to 40 grid points was established in each treatment area. A GPS reading will be taken at each point to establish its exact location.

Pre- and post-treatment data will be collected at the grid points or locations specified by FFS protocols. Sampling conducted at every grid point included: fuel transects, litter and duff samples, small mammal trapping, and photographs (figure 4). Sampling at every other grid point included coarse woody debris measurements and herpetofauna traps. Vegetation data were collected on 10 sample plots, 0.1 ha in size, located at every fourth grid point throughout each treatment area. Variable measurements and sampling for soils, entomology, and pathology were conducted on all vegetation sample plots. Bird census counts were completed on a 200-m grid within the treatment area. Fire behavior, nest productivity, and economics are measured at the treatment area level. In addition to FFS protocols, two 30-m drift arrays were constructed in each treatment area for sampling herpetofauna. Two studies have been added to those specified by FFS protocols. One will document treatment effects on

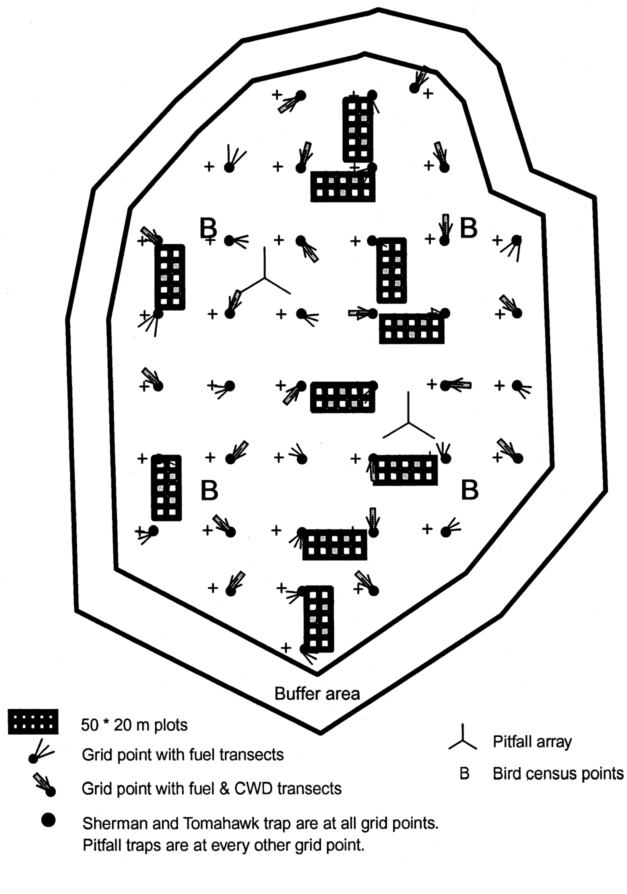

Figure 4. Typical treatment area layout for all sample and data collection.

decomposition and fluxes of carbon and nitrogen. Another will examine effects of fuel reduction on pollinating insects. All pretreatment data will be collected between May and December 2001. Specific descriptions of methods for each discipline are given below.

TREATMENTS

One of four treatments, as defined by FFS protocols, was assigned to each treatment area within a block using a random number table. Treatments include mechanical removal of fuels, prescribed burning, mechanical fuel reduction followed by prescribed burning, and an untreated control. The levels of mechanical reduction and prescribed burning are defined by FFS protocols to be sufficiently heavy so that if a wildfire occurred on a day with weather conditions at the 80^{th} percentile, 80 percent of the overstory trees would survive. Eightieth-percentile weather conditions during the wildfire season for the mountains of North Carolina (February through early April) would include a high temperature of 22^{o} C, low relative humidity of 34%, and peak 5-minute windspeed of 13m/sec (NCDC daily observations for Greenville/ Spartanburg airport). These parameters were used in the site module of BEHAVE to determine the maximum flame height that would occur with southern pine fuels. BEHAVE predicted a flame height of 3.1 m. Estimates of overstory tree mortality at this level of fire intensity (Waldrop and Van Lear 1979, Waldrop and Lloyd 1987) are far below 80 percent without fuels treatment. However, experience with prescribed burning in similar stands suggests that flame lengths and mortality would be much greater under those weather conditions, suggesting the difficulty of predicting fire behavior and mortality in southern stands. Therefore, thinning and burning levels will be prescribed that will reduce fuels and follow standard silvicultural practices for managed stands in the southern Appalachian Mountains.

Mechanical removal of fuels will be conducted by contract operators and will be specified according to typical operations conducted on neighboring USDA Forest Service Ranger Districts. A contract chainsaw crew will cut all trees over 6 feet tall and less than 4 inches dbh. In addition, all mountain laurel and rhododendron stems will be cut. When brush piles occur, several cuts will be required to keep the piles less than 4 feet high. No fuels will be removed from the site due to the high cost of operating in steep terrain. Mechanical fuel reduction will be conducted in the winter of 2001-2002.

Prescribed burning of each treatment area will be conducted the winter following mechanical reduction to allow drying and some decomposition of slash. The North Carolina Wildlife Resources Commission will conduct burning operations with assistance from USDA Forest Service personnel. Each treatment area will be burned during late winter or early spring of 2003. Ground crews will ignite strip headfires. Weather conditions and strip placement will be selected to produce flames from 1 to 2 m high. Such fires will likely result in topkill of all understory plants and some trees in the suppressed and intermediate canopy classes. The major objective of prescribed burning will be to remove the shrub layer.

VEGETATION

All vegetation variables were measured on all, or a portion of, ten 0.1 ha sample plots located systematically throughout each treatment area. Sample plots were established at grid points 2,6,10,14,18,22,26,30,34, and 38. Each plot was 50 by 20 meters in size. The long side of sample plots began at a grid point and followed a cardinal direction so that it ended at another grid point. The direction of the long side was chosen using random numbers from 1 to 4, representing north, east, south, or west, respectively.

At the time of measurement, cloth tapes were stretched along the two 50-m outer sides of the sample plot and another parallel and half way between the first two. Other tapes were placed perpendicular to those on the long sides and at 10-m intervals. The result was 10 subplots, each 10 by 10 meters in size (figure 5).

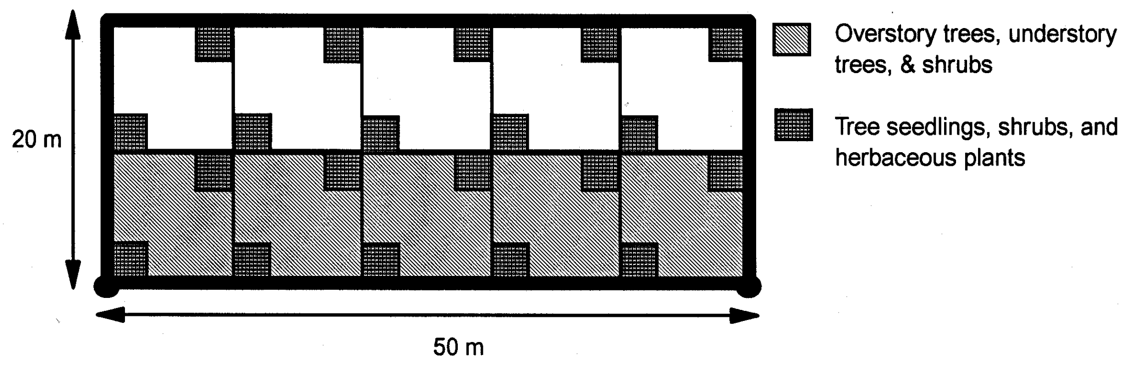

Figure 5. Layout of vegetation measurement subplots.

All trees 10 cm dbh or larger were measured in 5 of the 10 subplots. National protocols call for measurements in all 10 subplots. However, southern Appalachian forests are too dense to allow for sampling at that level. At each tree, an aluminum nail was used to place a numbered aluminum tag on the tree, approximately 2.5 m above ground. For each tree, the tree number, species, dbh, status, total height, merchantable height, height to live crown, height to dead crown, and crown condition were recorded. Dbh was measured by d-tape and recorded to the nearest mm. Status included: standing live, standing dead, dead and down, and harvested. All heights were estimated to the nearest meter. Crown condition was an estimate of percent cover. Incidence of diseases and/or beetles was recorded for each tree. Diseases were identified by causal species and beetles were identified as Southern pine beetle or *Ips*. Increment cores were extracted from 3 randomly selected trees to establish product age.

Saplings (trees >1.4 m tall and < 10 cm dbh) and shrubs were measured on the same five 10 by 10 m subplots, as were larger trees. Saplings were recorded by species, status, and dbh class. Status included live, topkilled, or harvested. Dbh classes included <3 cm, 3-6 cm, and >6 cm. Shrubs were recorded by species and an estimate of the percentage of the area covered by the shrubs' crowns.

A total of 20, 1m^2 quadrats was established in each vegetation sample plot to measure the herbaceous layer. Quadrats were located at the upper-right and lower-left corner of each 10 by 10 m subplot (figure 5). All trees < 1.4 m tall were recorded by origin and height class categories. Origin categories included first-year seedling, established seedling, or sprout. Height classes included < 10 cm, 10 to 50 cm, and 50 to 139 cm. Shrubs (<1.4 m tall) and all herbaceous species were recorded by species, cover class, and origin class. Cover classes included <1%, 1 to 10%, 11 to 25%, 26 to 50%, 51 to 75%, and > 75%. Origin class included germinant, established plant, or sprout.

Sample tally sheets for all vegetation variables are in the Appendix.

FUELS AND FIRE BEHAVIOR

The amount of forest floor material was determined by destructively sampling the forest floor material as opposed to estimating the weight by developing regression equations. Samples were randomly selected in areas that represent the full range of forest floor depth on the each treatment area. A pilot study using 50 forest floor samples from two treatment areas was conducted to determine the sample size need for the remaining areas. Based on the dry weight of litter and duff (F and H combined) samples, the sample size equation (Schaeffer and others, 1979) predicted that a total of 48 samples per treatment area would estimate the true population mean to within 2 percent. Therefore, one litter and one duff sample was collected at each of the 40 grid points in the remaining treatment areas. An additional 10 samples were collected from just outside each vegetation sample plot.

A wooden frame was used along with a cutter to collect each sample by layer (L and F/H) and each layer was bagged separately. Due to rapid decomposition rates in the Southeast, F and H layers and often indistinguishable and must be combined. After careful removal of the frame, each layer was measured in the center of each side of the square foot sample and recorded on the sample bags. The eight depths measured were then averaged by layer for that particular sample. To ensure the collection of all organic material, the duff sample was collected past the soil surface. Each sample was then washed to remove the soil and rock portion. They were air-dried and then dried in an oven set at 85EC until a constant weight is reached. The different size classes of woody material (0-3", 3-1", and 1-3") and other components (cones, bark and other vegetation parts) were separated out of the individual samples. The separation process supplements the woody material inventory by determining the woody component incorporated in the forest floor.

The amount of forest floor material removed by the prescribed fire is critical for defining vegetation and soil responses and smoke production. A series of eight duff pins will be used to determine the amount of forest floor material removed. The eight steel pins will be located on two perpendicular axes located at the far end of each woody fuel transect and marked with engineering flags to aid in relocating. Each pin will be pushed into the forest floor and mineral soil until the head of the pin is flush with the top of the litter layer. The location of the pins will have to be determined once other activities around the grid points are defined so that they are located in undisturbed areas. After the fire, each pin is relocated and the distance from the top of the pin to the top of the remaining forest floor is measured. The total distance from the top of the pin to mineral soil is also recorded for each pin.

The down dead woody fuels will be measured before and after treatment using Brown=s (1974) planar intercept method. Fuel will be classified by size class (0-1/4"=0-6mm, 1/4-1"=6-25mm, 1-3"=25-75mm, and 3+"=75+mm), decay class condition (sound and rotten), and the number of intercepts and diameters of 3+" diameter material by species. Three 50-foot transects were established approximately 6 feet away from each grid point and in a randomly selected direction. This method produced a total of 72,000 feet of fuel transects throughout the FFS study. All transects had a common starting point and the outer two transects were 45 degrees apart (figure 6). The beginning and end points were permanently marked with spikes and blue stake chasers.

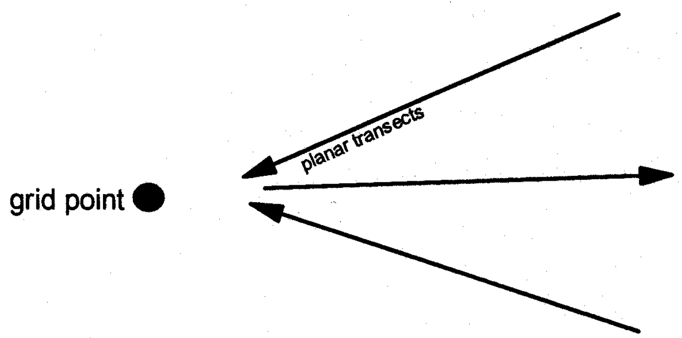

Figure 6. Arrangement of fuel transects at each grid point.

Fuel transect measurement began on the end farthest from the grid point for the two outer transects and at the end closest to the grid point for the center transect. One- and 10-hour fuels intercepts were counted along the first 6 feet and 100-hour fuels were counted along the first 12 feet. Fuels in the 1000-hr class were recorded by species, diameter, and decay class along the entire 50-foot transect. Litter and duff depth were measured to the nearest 0.1 inch at 12, 25, and 40 feet along each transect. Aboveground height of dead and down wood was measured along 1-foot sections beginning at 12, 25, and 40 feet. Sample tally sheets are in the Appendix.

Samples for estimating fuel moisture will be collected just prior to the application of the burn treatments. Forest floor samples will be collected by layer to represent the plot condition. These samples will be collected in moisture proof bottles, weighed, oven-dried at 95EC until there is no more weight loss, and then re-weighed. Woody fuel moisture content samples will also be collected by the different woody fuel size classes as defined previously. Moisture content will also be determined for the live fuel component. This will be done by vegetation class (grass, forb and shrub) and sampled to represent the entire plot. The moisture content is determined on an oven dry basis as defined above.

Fire behavior will be documented at each burn treatment plot to qualify the fire intensity between fire treatment plots (See field sheet FFS-Fuels-G, Appendix). Flame length will be measured as an ocular estimate on the flame front. Rate of spread will be estimated by timing the movement of the flaming front to cover a known distance. Flaming and smoldering stage duration will be measured during the course of the burn. The flame length and rate of spread will be taken as sets of measurements at regular intervals (i.e. every 15 minutes), throughout the lighting phase at selected grid points. In addition, flaming and smoldering duration will be ocularly estimated at the same selected grid points. Prior to and during the burning operations on the fire treatment plots, ambient temperature, relative humidity, and wind speed and direction will be collected as fire parameters (See field sheet FFS-Fuels-G, Appendix).

COARSE WOODY DEBRIS

Sample plots were established at every other grid point on all treatment areas. At each sampled grid point, a strip-plot (4 meters by 20 meters) was established with the center woody fuel transect line serving as the strip-plot center line (figure 7). Within each strip-plot only logs or parts of logs that were at least 1m in length and had a large end diameter 15cm or greater were measured and counted. The small end (>7.62cm) and large end diameters were measured on all qualifying logs or parts of logs that fell within the boundaries of the strip-plot. If a piece extended outside the strip-plot, diameters were measured at the line of intercept of the strip-plot boundary and CWD piece. Piece lengths were the lengths of the CWD within the strip-plot area. The length of the entire piece was measured to determine the midpoint of the CWD. If the midpoint was within the strip-plot, the piece was given an additional rating of ``1" for the Indicator Variable. If the midpoint fell outside the strip-plot the piece was given a rating of ``0" for the Indicator Variable.

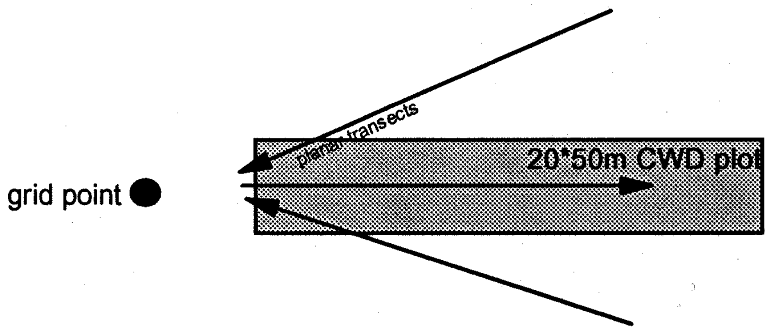

Figure 7. Position of CWD measurement plot relative to fuel transects.

In addition the species (if possible) and decay class of each log was be recorded. The following 5 decay classes were be used to rate the CWD (from Thomas 1979):

Class 1	Bark is intact; twigs are present; wood texture is sound; log is still round; original wood color.
Class 2	Bark is intact; twigs are absent; wood texture is sound or becoming soft; log is still round; original wood color.
Class 3	Bark is falling off; twigs are absent; wood texture is hard; log is still round; original color of wood is faded.
Class 4	Bark is absent; twigs are absent; texture of wood is soft, blocky Pieces; shape of log is oval; wood has faded to light yellow or gray.
Class 5	Bark is absent; twigs are absent; wood texture is soft and powdery; shape of log is oval; wood has faded to light yellow or gray.

SOILS AND THE FOREST FLOOR

Objectives:

1. To determine pre and post treatment mineralization/nitrification levels.
2. To determine pre and post treatment carbon, and nitrogen content in the O and A horizons and macronutrient content in the A horizon (first 10 cm, sometimes containing the upper part of the B_t horizon).
3. To determine pre and post treatment bulk density levels.

Methods:

Within each treatment area, there are ten 20 x 50 meter plots, established by vegetation crews, in which the soil sampling will take place. From each plot a total of 20 soil samples will be taken (the O horizon and the first 10 cm of mineral soil). Twelve samples (6 from the O horizon and 6 from the A and/or upper B horizon) will be taken and used for carbon, nitrogen and macronutrient analysis (Figure 8). These samples will be taken 1.5 to 2 m towards the center of the plot along each transect. Four more samples from the A horizon will be used to determine mineralization/nitrification (Figure 9). The other four (A horizon) samples of the twenty will be placed back in the ground for a 20-30 day in-situ period. After this period, these samples will be tested for mineralization and nitrification and contrasted to the prior samples.

The carbon, nitrogen and macronutrient levels will be obtained by combining the soil samples (O and A, on per plot basis) and then contracting the lab analysis work. Samples taken from corner subplots will be taken 2 m from each corner pin transecting toward the inside of the plot at 45^0 angles (Figure 8). Interior subplot samples will be taken at the mid points between each subplot and transecting 2 m toward the middle of the plot (Figure 8).

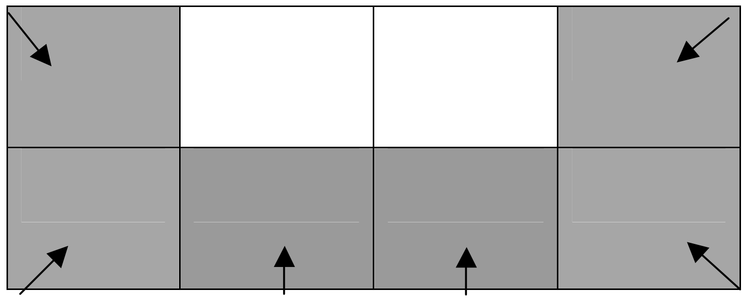

Figure 8. Carbon/Nitrogen/Macronutrient Sample Location. Gray shaded regions = subplot location, Carbon/Nitrogen/Macronutrient is taken on all lettered subplots. Lines correspond to sample location transect

Samples for mineralization/nitrification will be taken 2 m from each corner pin transecting toward the inside of the plot at 45^0 angles (figure 9).

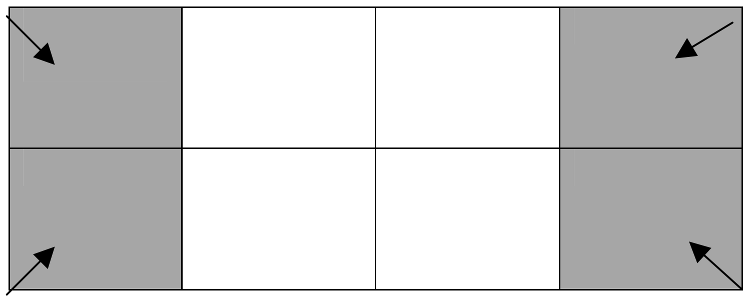

Figure 9. Mineralization/Nitrification Sample Location. Gray shaded regions = nitrification sample subplot location. Lines correspond to sample location transect.

There will be 10 bulk density samples taken per plot (5 on each 50 meter side). These bulk density samples will be taken by using a soil sampler (slide hammer) and a series of rings. The location of these samples will be on the long side of each plot. The samples will be taken starting 5 m from the of bottom corner of the plot and then every 10 m until the fifth sample is taken. Samples will also be taken along the adjacent side at the same dimensions. Each of sample points will be offset 2-5 meters outside the plot to compensate for boundary soil compaction (due to extensive research activity).

After collection, these samples will then be oven dried at 104°C for 16-24 hours. The samples will then be weighed and used to calculate the bulk density for each single unit. These measurements will then be averaged by plot to determine mean bulk density (pre/post treatment) that will demonstrate the difference (if any) among the treatment regimes.

Ten penetrometer measurements (to a three inch depth) will be taken at the same points as bulk density. These penetrometer measurements will likewise be averaged on a per plot basis (pre/post treatment) and can be used to show the difference (if any) among the treatment regimes.

CARBON AND NITROGEN CYCLING

Although not a component of the national protocols, this portion of the study will augment information from the soils discipline by explaining nutrient changes in nutrient fluxes as affected by treatment.

Objectives:

1) To quantify pools and fluxes of carbon and nitrogen in ecosystems under different fuel management practices.
2) To determine effects of prescribed burning and mechanical thinning (singly and in combination) on net carbon storage/loss at the landscape scale.

Pools to be measured: Aboveground biomass, belowground biomass, detritus, and soil.

Fluxes to be measured: Aboveground production, belowground production, decomposition of detritus (sticks and litter), belowground decomposition, litterfall, and soil respiration.

Methods

Pools

Aboveground biomass will be estimated from data collected as part of the national protocol from Whitaker vegetation plots (DBH, shrub cover, sapling size classes, clipping). Pool sizes will be estimated using allometric equations from the literature.

Belowground biomass will be determined by excavating soil monoliths from a subset (N = 10) of grid points from each treatment area. Monoliths will be 25 by 25 cm and excavated to a depth of 40 cm. Roots will be separated from soil, sorted by size class, weighed and analyzed for C and N.

Detritus - Pool size will be estimated using data collected as part of the FFS national protocol. Litter, duff, fuel, and coarse woody debris data will all be used. Subsets (N = 10 for each treatment area) of material collected in each class of detritus will be analyzed for C and N.

Soil - Pool size will be estimated using data collected as part of the FFS national protocol.

Fluxes
Aboveground production will be estimated using annual DBH measurements and shrub and sapling cover data collected as part of the FFS national protocol.

Belowground production - Fine root production will be estimated using root in-growth bags. A series of soil cores will be taken at a subset of grid points (N = 3-5) in each treatment area. All root material present in these soil cores will be carefully removed from the sample and the root-free soil will be placed into a nylon mesh bag. The nylon mesh bags will then be placed back into the soil. These bags will then be harvested every 2 months for two years (i.e. 12 root in-growth bags at each of 3 or 5 grid points in each treatment area. Roots growing into the bags will be sorted, weighed, and analyzed for C and N.

Aboveground Decomposition - Aboveground litter and wood decomposition will be estimated using litterbags and wooden dowels, respectively. Litterbags containing a known quantity of leaf litter will be placed on the forest floor, and collected every 2 months for one year, and every 3 months for a second year. Litter remaining in the bags at each sample date will be weighed and analyzed for C and N. A total of 60 litterbags (12 sample dates and 5 grid points) will be placed in each treatment area. Pine dowels of three different diameters (¼", ⅝", and 1⅛") and known mass will be placed on the forest floor, and sampled over a time course similar to the litterbag study. These dowels will be deployed at three randomly chosen grid points in each treatment area. Decomposition rates will be determined by mass loss over time, and all dowels will be analyzed for C and N at the time of sampling.

Belowground Decomposition - In conjunction with aboveground decomposition measures, belowground decomposition will be estimated using pine dowels (¼" diameter) that have been buried in the soil. These dowels will be driven into the soil to a depth of 20 cm and sampled over a time course similar to that described for the aboveground decomposition studies.
These belowground dowels will be deployed at three randomly chosen grid points in each treatment area. Decomposition rates will be determined by mass loss over time, and all dowels will be analyzed for C and N at the time of sampling.

Litterfall will be measured by placing collectors of known surface area on the forest floor, and periodically collecting, weighing and analyzing any litter that falls into them. This will also serve as an estimate of annual leaf production. There will be 3-5 such collectors in each treatment area.

Soil Respiration will be measured in the field by driving PVC pipe vertically into the soil to a depth of 20 cm, and periodically (every two months) measuring total soil CO_2 flux from the soil with an Infrared Gas Analyzer. There will be at least 5 of these pipes at each of 3 grid points in each of the 12 treatment areas.

WILDLIFE

Small Mammals.
Timber harvest and other disturbances that are commonly used as fuel reduction techniques affect forest structure and composition at macro- and microhabitat scales. Disturbance-caused changes to habitat structure have the potential to affect rodent populations and community composition. Microsites such as coarse woody debris (CWD), brushpiles, and structurally complex vegetation

provide cover and nest sites. Coarse woody debris also harbors fungi and invertebrate food sources for some rodents (Loeb 1996). Flushes of plant growth, seed production, and higher densities of invertebrates provide food resources in recently disturbed sites (Blake and Hoppes, 1986). Small mammals may be differentially affected by disturbance because of different microhabitat requirements (e.g., Dueser and Shugart, 1978, 1979; McComb and Rumsey, 1982; Seagle, 1985a, 1985b). Disturbed areas could function as rodent population sources or sinks by affecting reproductive rates, predation intensity, and survival (Sullivan, 1979; Loeb, 1999).

Small mammals, such as the common *Peromyscus* spp. likely play a primary role as seed dispersers and as prey for carnivorous mammals, birds and snakes (Sullivan, 1990). Their far-reaching influence on forest dynamics is illustrated by their link to gypsy moth (*Lymantria dispar*) populations (Elkinton and others 1996) and even the prevalence of Lyme disease (Jones and others 1998).

Both prescribed fire and mechanical thinning are commonly used as fuel reduction techniques to prevent large-scale wildfires. Prescribed fire, although a common land management technique in the coastal plain, is a relatively new tool to forest managers in the hardwood forests of the southern Appalachians. Hence, little is known about how small community responds to habitat changes due to prescribed fire, or how it might differ from response to mechanical thinning. The objective of this study is to determine the impacts of the three fuel-reduction treatments (compared to a control treatment) on the small mammal communities of the upland mixed hardwood forests of the southern Appalachians.

Live trapping of small mammals will occur during July and August of the year preceding treatment implementation (2001), and for at least one year post-treatment. Trapping is intended to determine abundance and diversity of species present. *Fire and Fire Surrogate* (*FFS*) protocols were revised in 2001 to allow closer spacing of traps; the following proposed methodology reflects these revisions. One Sherman live trap (7.7 X 9.0 X 23.3 cm) baited with oatmeal and peanuts will be placed at and midway between gridpoints (at 25-meter intervals). In order to estimate population density per unit area, trapping grids must be geometrically shaped (e.g., square or rectangular). Because of irregular treatment area shapes we will use 60 – 70 (at and between 30 – 35 gridpoints) Sherman traps in a square or rectangular grid layout. Additionally, eight Tomahawk #201 traps will be placed at approximately 100-m intervals within grids; Tomahawks will yield presence-absence information on “meso-mammals” (e.g., skunks, o’possums, raccoons) only. Traps will be open continuously for 10 nights and checked each morning as specified by *FFS* protocols. All four treatment areas within replicate blocks will be trapped simultaneously. Small mammals will be weighed and measured (head-body and total length), sexed, tagged in the right ear with an individually numbered tag (size 1 Monel; National Band and Tag Co., Newport KY), and released at capture site. Mesomammals will be recorded and released. Trap number will be recorded for all captured animals.

Habitat measurements including CWD, vegetation structure, litter depth, and others taken by the Clemson vegetation crew before and after treatment implementation, will be used to assess the how treatment-related changes in habitat and microhabitat structure influence small mammal species richness, diversity, density, and relative abundance.

Small mammals were trapped as described above during July and August 2001 (pre-treatment data). Post-treatment trapping will be conducted during July and August 2002.

Herpetofauna.

Species richness of herpetofauna in the southern Appalachian mountains rivals any in the United States (Kiester, 1971; Conant and Collins, 1991). Petranka and Murray (2001) estimate the biomass of a streamside salamander community to be 24 times higher than bird biomass estimates from Hubbard Brook in New Hampshire (Burton and Likens, 1974*a*, 1975*b*). Reptiles and amphibians are prey for many vertebrate predators (Pough and others, 1987). Clearly, herpetofauna are an important component of biological diversity, and also serve an important role in supporting the biological diversity of vertebrates.

Several studies in the southeastern United States suggest that timber harvesting can adversely affect local amphibian populations, especially salamanders (Blymer and McGinnes, 1977; Pough and others, 1987; Ash, 1988, 1997; Petranka and others, 1993, 1994; deMaynadier and Hunter, 1995; Phelps and Lancia, 1995). Canopy removal results in a warmer, drier microclimate, and reduced leaf litter cover and depth that could cause salamanders to desiccate (Ash, 1988; Petranka and others, 1993; deMaynadier and Hunter, 1995; Harpole and Haas, 1999). Some studies report that salamanders virtually disappear from sites following clearcutting, and their populations in the southern Appalachians take at least 20 years to fully recover (Ash, 1988, 1997; Petranka and others, 1993, 1994; but see Adams and others, 1996; Harper and Guynn, 1999). DeMaynadier and Hunter (1995) suggest that timber harvesting techniques that retain adequate microhabitat could mitigate impacts on many amphibian species.

The same conditions that may be detrimental to amphibians appear to benefit reptiles (Phelps and Lancia, 1995; Greenberg and others, 1994; Adams and others, 1996). Most reptile species require warm temperatures (associated with higher light levels) for egg incubation and successful development of hatchlings (Goin and Goin, 1971; Deeming and Ferguson, 1991). Greenberg (2001) reported higher relative abundance of reptiles but no difference in salamander abundance in extended (0.1 – 0.15 ha) canopy gaps compared to forested controls. However, most studies of herpetofaunal response to timber harvesting conducted in the southern Appalachians focus on salamander response and do not address the response of reptiles.

As the ecosystem management paradigm has gained momentum in the past decade, forest managers and ecologists have suggested that forest management strategies mimic natural disturbance (Hansen and others, 1991; Greenberg and others, 1994). Studies in fire-adapted ecosystems indicate that the response of reptiles to clearcutting and fire is similar (e.g., Greenberg and others 1994). However, little work has been done to assess herpetofaunal response to fire or other fuel reduction techniques in the southern Appalachians. The objective of this study is to determine the impacts of the three fuel-reduction treatments (compared to a control treatment) on the herpetofaunal community of the upland mixed hardwood forests of the southern Appalachians.

Fire and Fire Surrogate herpetofauna trapping protocol revisions (April 2001), state that "most sites… [agree that effort] far exceed[s] the return (in terms of sample sizes)," and stated that herpetofaunal trapping is now an optional part of the *FFS* standard protocol. The memo indicates that if herpetofauna surveys are conducted, established *FFS* protocols (2000) should be used as guidelines. However, we determined that the 2000 protocols did not effectively sample the herpetofaunal community, and, in agreement with other Wildlife Site Managers, was not worth the effort. Instead, drift fence arrays with pitfall and funnel traps will be established at the Green River Gamelands site to assess herpetofaunal response (as measured by relative abundance and diversity) to three fuel reduction techniques and a control. Two drift arrays $\geq$100-m apart were established in each treatment area.

Arrays will include three 7.6-m sections of aluminum flashing positioned at approximately 120^{o} angles (in a "Y" shape), with one 19-liter bucket buried at each section end such that its rim is flush with the ground surface, and a fourth pitfall shared by all three "arms" in the center of the "Y." Double-ended funnel traps will be placed on both sides of each arm for a total of six funnel traps. Wooden stakes will be added for support. A moist sponge will be placed in each bucket to provide moisture and cover for captured herpetofauna.

All traps (all treatment areas in all three replicate blocks) will be open continuously during late summer and early fall (the earliest possible date) during the year prior to treatment implementation (2001) and at least one year post-treatment (2002). Animals will be weighed, measured (snout-vent and total length), sexed and marked by cohort (the year captured), replicate block and treatment area by toe- or scale (snakes) clipping.

Habitat measurements including CWD, vegetation structure, litter depth, and others taken by the Clemson vegetation crew before and after treatment implementation, will be used to assess the how treatment-related changes in habitat and microhabitat structure influence herpetofaunal species richness, diversity, density, and relative abundance.

Drift fence arrays were established during summer 2001, and traps were open continuously from 15 August through 11 October 2001 (pre-treatment). Traps will be re-opened from May through August (at least) 2002 after treatments are implemented.

Avifauna
The influence of vertical and horizontal vegetation structure on bird communities is well established (e.g., MacArthur and MacArthur 1961). Silvicultural disturbance, such as prescribed fire and mechanical thinning, affect habitat structure and, due to increased light levels and primary productivity, may promote a higher density of insects, and increased fruit production (Blake and Hoppes, 1986; Martin and Karr, 1986). Several studies report higher species richness, diversity, and density in silviculturally disturbed sites compared to mature forest (e.g., Annand and Thompson, 1997; Baker and Lacki, 1997). However, many bird species have specific habitat requirements, such that disturbances do not have the same effect on all species (Thompson and others, 1995; Annand and Thompson, 1997).

The objective of this study is to determine the impacts of three fuel-reduction treatments (compared to a control treatment) on avian abundance and diversity, nest productivity, and the functional response of the bark-gleaning guild of the upland mixed hardwood forests of the southern Appalachians.

We will assess the diversity and abundance of birds in the treatments of this study with point count censuses. Point counts are a standardized method (Ralph and others, 1993) to assess the diversity and abundance of birds. At least three points will be established within each treatment area, spaced at 200 m intervals. All points within treatment areas will be surveyed for 10 minutes each during three separate visits during the breeding season (April 15 – June 30) (as indicated in the *FFS* national protocol revisions issued April, 2001). All birds detected by sight or sound within a 50-m radius are recorded (one record per individual bird, despite multiple detections during the point count). In addition, "flyovers" are recorded. All point counts will be conducted within 3 hours after sunrise. Beginning and ending time of each detection will be recorded such that the data can be compared with local Breeding Bird Surveys (using only the first 3 minutes).

Nest productivity will be assessed by standardized methods using Ralph and others, 1993; Martin and Geupel, 1993; Martin and others, 1997. Two randomly picked replicates of each treatment (8 treatment areas) will be searched for bird nests. Search method (e.g., follow or flush parents; systematic searches), nest stage (building, laying or incubating eggs; nestlings), and nest contents will be recorded. Nests will be monitored to determine the number of young successfully fledged. Microhabitat measurements will be made at nest sites after nesting activity is completed, following the national BBIRD program protocol, Characteristics vegetation supporting each nest (e.g., vegetation strata, shrub or tree species, height, and diameter) and specific location (e.g., nest height, cover, aspect) will be recorded. In addition, trees and snags ≥1.3 m height will be tallied by species and size class (trees: < 8 cm; 8-22.9 cm; 23-28 cm; snags: < 12 cm; ≥ 12 cm) within a circular plot that extends 11.3 radius from the nest. The data gathered will be analyzed by nesting category, species, and overall productivity among treatments.

The functional response of woodpeckers and other bark-gleaning birds (e.g. chickadees, titmice, nuthatches, creepers) will be evaluated using focal observations of foraging behavior developed and adapted from Weikel and Hayes (1999). Foraging behavior of woodpeckers and bark gleaning species will be surveyed at each treatment area during 6 two-hour observation periods for a total of 144 survey hours (treatment area visits will be rotated such that a similar number of sample-hours will be conducted in each if fewer than 6 visits are made). Grids will be walked systematically (using a different route with each sample). Individual woodpeckers or bark gleaners that are clearly foraging will be recorded using a "snapshot" approach. Only 3 records of a given species will be recorded within a treatment area each day. The same species will be recorded two times in a row only if observations are ≥ 200 m apart.

Data recorded will include species and sex, foraging behavior (glean, probe, peck, scale, excavate), the amount of time spent foraging on a tree, and foraging position (vertical: lower, middle, or upper third of tree; horizontal: tree bole or branch; branch position: proximal, middle, distal, live or dead), will be recorded. Trees will be categorized as hardwood or conifer, and live or dead. Foraging trees and a randomly selected tree the same category (hardwood or conifer; live or dead) and within 50 m will be measured following methods adapted from Weikel and Hayes (1999). Tree species, dbh, condition, foliage color and retention, bark retention, evidence of beetles (pitch tubes; exit holes) and measures of fire scarring will be recorded.

Habitat measurements including CWD, vegetation structure, litter depth, and others taken by the Clemson vegetation crew before and after treatment implementation, will be used to assess the how treatment-related changes in habitat and microhabitat structure influence avifaunal species richness, diversity, density, and relative abundance.

Three point counts per treatment area were conducted between 17 May and 25 June 2001 (pretreatment data) as described above. Foraging surveys were conducted for 2-6 hours (1-3 two-hour visits per treatment area; one area not surveyed) per treatment area. Five nests (each of different species) were located in 3 treatment areas. Due to a late start (treatment areas were not yet established or delineated by early breeding season) insufficient time was devoted to foraging surveys and nest searches. FFS National protocols indicate that bird surveys and associated work should be suspended during the year after mechanical thinning and prior to prescribed fire. However, we will conduct bird surveys, nest searches and foraging surveys during 2002 and 2003 (at least). The 2002 (post-treatment) avian field season will begin on 15 April and continue through 30 June.

ENTOMOLOGY

The southern pine beetle (SPB), *Dendroctonus frontalis* Zimmerman, is the most serious insect pest of pines in the southeastern United States. It can attack most species of pine in its range, but prefers shortleaf pine (*Pinus echinata* Mill.) and loblolly pine (*P. taeda* L.) in the southern states. Increases in SPB activity appear to be closely related to changes in forest structure (Hedden 1978). The number of overstocked, pure pine stands is greater now than at any time in the past (USDA Forest Service 1988). These stand conditions, which favor SPB attack, are due to a combination of the abandonment of agricultural land and the exclusion of fire.

Silvicultural practices, including fire and thinning, can be used to reduce losses from the SPB (Belanger and others 1993). The disturbance caused by these silvicultural techniques may cause short-term increases in SPB activity due to short-term adverse effects on tree and stand vigor (Hedden and Belanger 1985). However, both fire and thinning can result in long-term reduction in SPB activity by reducing pine density and increasing individual tree vigor (Belanger and others 1993).

The objective of the entomology section of the southern Appalachian FFS Study is to determine the short-term and long-term impact of mechanical fuel reduction and prescribed fire, alone and in combination, on potential losses from bark beetles.

During the fall of 2001, the presence and absence of trees with bark beetle mortality will be censused. At each grid point within the 12 10-ha stands, trees that are clearly under beetle attack will be recorded. The following data from each infected trees will be noted: direction and distance from the grid point, tree species, bark beetle species responsible for mortality, tree diameter, and beetle attack stage (1, 2, or 3). These same data will be collected each year following the stand treatments.

In addition to national protocols a study of insect pollinators will be initiated. This study proposes to examine the effect of fire and fire surrogate treatments on pollinators in the understory plant community using the following methods.

Trapping

Two malaise traps will be operated in each plot for 5 days each month from March through October. To reduce cost we will move traps between study locations so that we only need one set of traps for the entire study. Bees and butterflies will be identified from the samples.

In addition to malaise traps we will test traps constructed from colored bowls as an additional method of surveying for bees. Bees are attracted to the color and attempt to drink the sugar water in the bowls. A percentage falling in is captured. Initial trials will include video taping the pollinator visits and behavior at the bowls to determine the numbers that visit and are subsequently captured and whether the bowls are biased in the species that they capture.

Visual Survey

We will walk the plots three times (April, July and September) per year stopping at 5 randomly selected grid-points to do a visual survey of flowering plants within 3 m of each point. Surveys will include recording flower abundance, plant species in flower, and pollinators present. Pollinators will be collected if necessary to identify them.

Cavity Nesting Bees and Wasps
One potential effect of fire on forest ecosystems is the removal (or increase) in the amount of large woody debris. Cavity nesting bees and wasps rely on holes in dead trees and branches for nesting sites. We will place nesting blocks at two grid points in each plot to assess the abundance of nesting bees or wasps and whether or not fire or fire surrogate treatments affects the numbers of nests.

PATHOLOGY
The core variable to be measured will be the presence and incidence of Ophiostomoid fungi in root samples. Intraplot sampling will be keyed to the 50-m square grid of permanent sample points. An initial survey of all treatment areas was conducted in order to mark trees that have pre-existing symptoms so as to not confuse these with subsequent treatment effects. Observations consisted of above-ground crown symptoms based upon a rating scale developed by the Institute of Tree Root Biology (TRB). Four symptom classes are recognized ranging from healthy to moribund. Determinants involved in these crown symptom classes are based upon foliar color, needle/leaf size, and internode length, with chlorosis and off-green color being the primary character defining symptomatic trees.

The pre-treatment data collection included all trees over 10 cm in diameter in 0.1 ha vegetative sample plots. National protocols specify that this work will be done on all trees in the treatment area. However, a survey such as that is not feasible in dense Southeastern forests. Symptomatic trees were tagged with fire-resistant metal tags that are numbered sequentially. Data collection on all symptomatic, putative root diseased trees consisted of recording the above mentioned crown symptoms, dbh, crown position, and signs of other distress agents (such as beetle pitch tubes, exit holes, etc.). Only conifers will be included in this study.

Pre-treatment data collection involves woody root samples taken from symptomatic trees via careful excavation of lateral roots that are near the soil surface. A minimally invasive procedure will be used that involves the sampling of intact root tissue by means of an increment hammer. This cautionary method is crucial in that minimal tissue disruption is essential B excessive wounding will cause anomalous insect attraction. Such undesirable impacts would confound interpretation of treatment effects relating to entomological data. To minimize these potential confounding effects, the pretreatment survey will be conducted in the following manner.

Vegetation crews, who are trained in this pathology protocol, will identify trees that are symptomatic (i.e. potential root diseased trees). Such trees will be identified by the tags installed during vegetation sampling. Root samples will not be taken from identified symptomatic trees until and unless the insect flight season has passed. Thus, root samples from identified, symptomatic trees will be obtained during late fall or after insect flights have ceased. Two symptomatic trees and one asymptomatic tree will be sampled from each sample plot.

During each sampling interval at least two roots having a minimum diameter of about 5 cm will be unearthed for a distance of one meter from the base of each selected tree. Roots should be selected on opposite faces of each tree, one designated as root AA≅, the other as root AB≅. Samples from each root will consist of three 5-mm-diameter cores taken with an increment hammer from the upper face of each root. The increment hammer will be sterilized between each individual root sampling by spraying to runoff from a spray bottle with 95% ethanol. The increment core samples will be grouped for each root, either AA≅ or AB≅, and will be sealed in a plastic zip-lock bag which will be labeled with plot and tree numbers, and taken to the laboratory in an ice chest. Samples will be refrigerated until culturing, which will be done as soon as practically possible.

To prepare samples for culturing, each core will be aseptically sliced into 1-mm thick cross sections, producing a total of at least 12 sections for the total number of cores within that sample. Five or six of these chips from each root will be placed on one plate with malt extract agar (MEA) and on another plate with malt extract agar with the addition of 200 ppm cycloheximide (CMEA). The chips from root AA≅ will be placed on the media on one half of the plate and the chips from root ≅B≅ will be placed on the other half. Each plate will be sealed with parafilm and incubated in the laboratory at room temperature (21-22 ^{0}C) for at least 10 days. Plate reading will involve visual inspection of the fungal colonies growing from each chip. This will be done at periodic intervals so as to obtain the greatest incidence of fungal colonies possible within each culture plate but to avoid overgrowth by faster-growing fungi such as *Trichoderma* or *Penicillium*. The first step in the identification of possible Ophiostomoid fungi will be done by examining at 200-400X each colony consisting of dark-pigmented hyphae. Promising cultures will be subcultured and after pure cultures are obtained these will be identified and subcultures furnished to TRB officials for analysis and possible further study.

Post treatment sampling will be similarly conducted. During the second and fourth years post-treatment, treatment plots will be observed and sampled relative to crown symptoms. Newly symptomatic trees will be tagged, noted, and root samples taken and analyzed as above.

The above protocol focuses on Ophiostomoid fungi. Since most of the study plots are located on sites with clay soils and these stands are especially predisposed to littleleaf disease, it is planned that additional fungal isolations, specifically for *P. cinnamomi*, will be done in the treatment and control plots after thinning and burning have been completed. In plots which have a high sand component, and which contain symptomatic eastern red cedar, the above root sampling protocol will be conducted on this species and resulting root cultures examined for presence of *H. annosum*.

TREATMENT COSTS AND UTILIZATION ECONOMICS

The validation of an existing harvest treatment cost simulation model with compartment-level data first requires the per unit area costs of associated activities at the site level, such as slashing, prescribed burning, etc. Study personnel will also record times for the associated activities. Agreements to allow monitoring of operating times and to provide scale records by compartment will be built into contracts (or formally agreed upon in advance with purchasers) at the site level. To provide realistic estimates of costs, information will be collected from areas where an efficient operations layout is used and the treated area is large enough to be cost efficient.

A compartment is defined, for purposes of this portion of the study, as the smallest unit for which it is readily feasible to segregate gross harvesting production and operating time data. Due to the distance between treatment areas, each treatment area will serve as an individual harvest compartment. In some cases, the area served by a single landing would make an easily identified compartment. Compartment-level harvest productivity data will be collected for chainsaw crews felling understory trees and shrubs. The dates and approximate times each person began and finished operating in each compartment will be recorded on paper. The contractor will provide the average hourly wage paid to crew members.

Estimates of burning costs will use an Aexpert opinion≅ methodology. Analysis will be based on information provide by individuals knowledgeable about burning under local conditions on similar plots of land with units sized and staffed for operational treatments. This information will be related to the treatment units.

A sample of 40 disks per major tree species (1-2 inches thick) will be provided to the California Forest Products Laboratory from each block. This sample will include 20 disks removed from the butts of sub-merchantable size trees and 20 disks removed from the top of the first log of merchantable trees. The disks should cover the diameter range of each group.

A sample of tree ages will be collected by taking increment cores from three trees in each vegetation sample plot. The objective is to provide an estimate of tree age by species and size class at a minimum cost and site-specific sampling details should be negotiated with the PNW Station.

LITERATURE CITED

Adams, J.P., M.J. Lacki, M.D. Baker. 1996. Response of herpetofauna to silvicultural prescriptions in the Daniel Boone National Forest, Kentucky. Proc. Ann. Conf. Southeast. Ass. Fish and Wildl. Ag. 50, 312-320.

Annand , E. M., F. R. Thompson. 1997. Forest bird response to regeneration practices in central hardwood forests. J. Wildl. Manage. 61, 159-171.

Ash, A.N. 1988. Disappearance of salamanders from clearcut plots. J. Elisha Mitchell Sci. Soc. 104, 116-122.

Ash, A., 1997. Disappearance and return of plethodontid salamanders to clearcut plots in the southern Blue Ridge Mountains. Con. Biol. 11, 983-989.

Baker, M. D., M. J. Lacki. 1997. Short-term changes in bird communities in response to silvicultural prescriptions. For. Ecol. Manage. 96, 27-36.

Belanger, R. P.; Hedden, R. L.; Lorio, P. L. 1993. Management strategies to reduce losses from the southern pine beetle. South. J. Appl. Forest. 17:150-154.

Blake, J. G., W. G. Hoppes. 1986. Influence of resource abundance on use of tree-fall gaps by birds in an isolated woodlot. Auk 103, 328-340.

Blymer, M.J., B.S. McGinnes. 1977. Observations on possible detrimental effects of clearcutting on terrestrial amphibians. Bull. Md. Herp. Soc. 13, 79-83.

Brown, J. K. 1974. Handbook for inventorying downed woody material. GTR-INT-16. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 24.

Burton, T.M., G.E. Likens. 1975*a*. Energy flow and nutrient cycling in salamander populations in the Hubbard Brook Experimental Forest, New Hampshire. Ecol. 56, 1068-1080.

Burton, T.M., and G.E. Likens. 1975*b*. Salamander populations and biomass in the Hubbard Brook Experimental Forest, New Hampshire. Copeia 1975, 541-546.

Conant, R., J.G. Collins. 1991. A field guide to reptiles and amphibians of eastern and central North America. Boston: Houghton Mifflin Co.

Deeming, D.C., M.W.J. Ferguson. 1991. Physiological effects of incubation temperature on embryonic development in reptiles and birds. In: Deeming, D.C., M.W.J. Ferguson (Eds.), Egg Incubation: its Effects on Embryonic Development in Birds and Reptiles. Cambridge University Press, New York, 32-37.

deMaynadier, P.G., M.L. Hunter, Jr. 1995. The relationship between forest management and amphibian ecology: a review of the North American literature. Envir. Rev. 3, 230-261.

Dueser, R.D., H.H. Shugart, Jr. 1978. Microhabitats in a forest-floor small mammal fauna. Ecol. 59, 89-98.

Dueser, R.D., H.H. Shugart, Jr. 1979. Niche pattern in a forest floor small mammal fauna. Ecol. 60, 108-118.

Elkinton, J.S., Healy, W.M., Buonaccorsi, J.P., Boettner, G.H., Hazzard, A.M., Smith, H.R., Liebhold, A.M. 1996. Interactions among gypsy moths, white-footed mice, and acorns. Ecol. 77, 2332-2342.

Goin, C.J., O.B. Goin. 1971. Introduction to Herpetology. W.H. Freeman and Company, San Francisco.

Greenberg, C.H. 2001. Response of reptile and amphibian communities to canopy gaps crated by wind disturbance in the southern Appalachians. For. Ecol. and Manage. 148:135-144.

Greenberg, C.H., J.D. Lanham. 2001. Breeding bird assemblages of hurricane-created gaps and adjacent closed canopy forest in the southern Appalachians. For. Ecol. and Manage. 154:251-260.

Greenberg, C.H., D.G. Neary, L.D. Harris. 1994. Effect of high-intensity wildfire and silvicultural treatments on reptile communities in sand pine scrub. Con. Biol. 8, 1047-1057.

Hansen, A.J., T.A. Spies, F.J. Swanson, J.L. Ohmann. 1991. Conserving biodiversity in managed forests: Lessons from natural forests. BioSci. 41, 382-392.

Harper, C.A., D.C. Guynn, Jr. 1999. Factors affecting salamander density and distribution within four forest types in the southern Appalachian mountains. For. Ecol. Manage. 114, 245-252.

Harpole, D.N., C.A. Haas. 1999. Effects of seven silvicultural treatments on terrestrial salamanders. For. Ecol. and Manage. 114:349-356.

Hedden, R. L. 1978. The need for intensive forest management to reduce southern pine beetle activity in east Texas. South. J. Appl. For. 2:19-22.

Hedden, R. L.; Belanger, R. P. 1985. Predicting susceptibility to southern pine beetle attack in the Coastal Plain, Piedmont, and Southern Appalachians. p. 233-238 *in* Proc. Integrated pest Manage. Res. Symp., Braham, S. J. and R. C. Thatcher (eds.). USDA For. Serv. Gen. Tech. Rep. SO-56.

Hicks, R. R., Jr.; Howard, J. E.; Watterson, K. G. 1978. The role of tree vigor in susceptibility of loblolly pine to southern pine beetle *in* Proceed. fifth North Amer. For. Biol. Work. p 177-181. Hollis, C. A. and A. E. Squillace, eds. Univ. Fla. Schl. For. Resour., Gainesville, FL.

Jones, C.G., Ostfeld, R.S., Richard, M.P., Schauber, E.M., Wolff, J.O. 1998. Chain reactions linking acorns to gypsy moth outbreaks and Lyme disease risk. Sci. 279, 1023-1026.

Kiester, A.R. 1971. Species density of North American amphibians and reptiles. Syst. Zoo. 20, 127-137.

Loeb, S.C. 1996. The role of coarse woody debris in the ecology of southeastern mammals. In: McMinn, J.W., D.A. Crossley, Jr. (Eds.), Biodiversity and Coarse Woody Debris in Southern Forests. USDA For. Serv. Gen. Tech. Rep. SE-94, 1108-118.

Loeb, S.C. 1999. Responses of small mammals to coarse woody debris in a southeastern pine forest. J. Mammal. 80, 460-471.

MacArthur, R.H. and J.W. MacArthur. 1961. On bird species diversity. Ecology 42:594-598.

Martin, T. E., J. R. Karr. 1986. Patch utilization by migrating birds: resource oriented? Ornis Scand. 17, 165-174.

Martin, T. E.; C. Paine; C. J. Conway; W. M. Hochachka [and others]. 1992. BBIRD: Breeding Biology Research & Monitoring Database. BRD, Field Protocol, Montana Cooperative Wildl. Res. Unit, Univ. of Montana, Missoula, Montana. 64p.

Martin, T. E., and G. R. Geupel. 1993. Nest monitoring plots: Methods for locating nests and monitoring success. J. Field Ornithol. 64(4):507-519.

McComb, W.C., R.L. Rumsey. 1982. Response of small mammals to forest clearings created by herbicides in the central Appalachians. 1982. Brimleyana 8, 121-134.

Petranka, J.W., M.E. Eldridge, K.E. Haley. 1993. Effects of timber harvesting on southern Appalachian salamanders. Con. Biol. 7, 363-370.

Petranka, J.W., M.P. Brannon, M.E. Hopey, C.K. Smith. 1994. Effects of timber harvesting on low elevation populations of southern Appalachian salamanders. For. Ecol. Manage. 67, 135-147.

Petranka, J.W., and S.S. Murray. 2001. Effectiveness of removal sampling for determining salamander density and biomass: a case study in an Appalachian streamside community. Journal of Herpetology 35:36-44.

Phelps, J.P., R.A. Lancia. 1995. Effects of a clearcut on the herpetofauna of a South Carolina bottomland swamp. Brimleyana 22, 31-45.

Pough, F.H., E.M. Smith, D.H. Rhodes, A. Collazo. 1987. The abundance of salamanders in forest stands with different histories of disturbance. Forest Ecol. Manage. 20, 1-9.

Ralph, C. John; G. R. Geupel; P. Pyle [and others]. 1993. Handbook of field methods for monitoring landbirds. Gen. Tech. Rep. PSW-GTR-144. Albany, CA: USDA, FS, Pacific Southwest Research Station. 41p.

Schaeffer, Richard L.; Mendenhall, William; Ott, Lyman. 1979. Elementary Survey Sampling. North Scituate, MA: Duxbury Press. 278 pp.

Seagle, S.W. 1985a. Patterns of small mammal microhabitat utilization in cedar glade and deciduous forest habitats. J. Mammal. 66, 22-35.

Seagle, S.W. 1985b. Competition and coexistence of small mammals in an east Tennessee pine plantation. Am. Midl. Nat. 114, 272-282.

Sullivan, T.P. 1979. Demography of populations of deer mice in coastal forest and clear-cut (logged) habitats. Can. J. Zool. 57, 1636-1648.

Thomas, J.W., Ed. 1979. Wildlife habitats in managed forests; the Blue Mountains of Oregon and Washington. Agric Handbook No. 553. U.S.D.A. Forest Service, 512p.

Thompson, F. R., III, J. R. Probst, M. G. Raphael. 1995. Impacts of silviculture: overview and management recommendations. In: Martin, T.W., Finch, D.M. (Eds.), Ecology and management of neotropical migratory birds. Oxford Univ. Press, New York, 201-219.

USDA Forest Service. 1988. The South's fourth forest: Alternatives for the future. For. Res. Rep. No. 24, Washingto, DC. 512 p.

USDA Natural Resources Conservation Service. 1978. Soil Survey of Polk County, North Carolina. U.S. Government Printing Office: 1998-432-697/60527/NRCS. 218 pp.

Waldrop, Thomas A.; Van Lear, David H. 1984. Effects of crown scorch on survival and growth of young loblolly pine. Southern Journal of Applied Forestry 8(1):35-40.

Waldrop, Thomas A.; Lloyd, F. Thomas. 1988. Precommercial thinning a sapling-sized loblolly pine stand with fire. Southern Journal of Applied Forestry 12(3):203-207.

Weikel, J.M., and J.P. Hayes. 1999. The foraging ecology of cavity-nesting birds in young forests of the northern coast range of Oregon. Condor 101:58-66.

Appendix – Sample Tally Sheets

Overstory Trees

FFSS 0.1 ha Tally Sheet Area ________ Grid Point ______Date ___________
All trees ∃ 10 cm dbh; number each tree
Status 1=standing, 2=standing dead (by), 3=dead&down, 4=harvested
Crown Condition- describe foliage transparency, branch dieback, vigor
.

Tree #	Spec	DBH (cm)	Status	Total ht (m)	Merch ht (m)	Ht to Live Crown	Ht to Dead Crown	Crown Condition	Beetles (B) or Disease (D)	Ips (I) or SPB (S)	Bole char ht (m)	Tree Age 3 samps

Midstory Trees and Shrubs

FFFS 10*10m subplots (3 per 0.1 ha)   Area___Grid Point__Subplot no.__ Date ________

Saplings (>1.4 m tall & < 10 cm dbh) and Shrubs
dbh class: 1=<3cm, 2=3-6cm, 3=>6cm
Status: 1=live, 2=topkilled (by), 3=harvested

Sapling species	Sapling status	Sapling dbh class		Shrub Species	Shrub % cover

Ground Vegetation

FFSS 1m^2 plots Area_____ Grid point_____ Subplot_____ Date _________

Tree seedlings - measure all 20 subplots - tally by origin and ht class categories
Shrubs and herbs - measure 12 subplots - estimate % cover and record origin
Cover class: 1=<1, 2=1-10, 3=11-25, 4=26-50, 5=51-75, 6=>75
Shrub and herb origin: germinants (G), established plants (E), sprouts (S)

Subpl ot num	Tre e Spe c	1st yr <10 cm	1st yr 10-50 cm	1st yr >50 cm	establ <10 cm	esta bl 10-50 cm	esta bl >50 cm	sprou t <10 cm	sprou t 10-50 cm	sprou t >50 cm	Shru b or herb spec	Shru b or Herb Cov er class	Shrub or Herb origin

Coarse Woody Debris

FFSS CWD Tally Sheet Area ______________ Grid Point _______ Date ______________

4*20m plot along center fuel transect at every other grid point
Measure logs ∃15 cm large end diameter an∃ 1 m long
Measure small end dia and large end dia along plot boundary
Determine midpoint only to see if it is in or out

Decay Class
1 Bark is intact; twigs are present; wood texture is sound; log is still round; original wood color.
2 Bark is intact; twigs are absent; wood texture is sound or becoming soft; log is still round; original wood color.
3 Bark is falling off; twigs are absent; wood texture is hard; log is still round; original color of wood is faded.
4 Bark is absent; twigs are absent; texture of wood is soft, blocky Pieces; shape of log is oval; wood has faded to light yellow or gray.
5 Bark is absent; twigs are absent; wood texture is soft and powdery; shape of log is oval; wood has faded to light yellow or gray.

	Species	Decay Class 1-5	Small dia (cm)	Large dia (cm)	Length inside plot (cm)	Total Length (cm)	Midpoint (total/2)	Midpoint in Plot? 0-no 1-yes
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								
11								

Fuels and Fire Behavior

Fire Behavior Documentation (FFS-Fuels-_) Date:__________
Study Site: __________________________
Unit Identification: _____________________
Observers: __________________________

General Information	
Firing technique used:	
Start time of ignition:	
Time ignition is completed:	
Burnout time:	
Elapsed time:	
Number of strips or spots:	
Spacing of strips, spots or backlines, etc.:	
Other pertinent information:	
Fire Weather Forecast - Day of Burn	
Zone:	
Time and Date:	
Today	
Sky/Weather:	
Maximum Temps:	Trends:
Minimum RH:	Trends:
Winds (Slope/Valley):	
Winds (Ridgetop):	
LAL:	
Chance of wetting rain:	
Tonight	
Sky/Weather:	
Maximum Temps:	Trends:
Minimum RH:	Trends:
Winds (Slope/Valley):	
Winds (Ridgetop):	
LAL:	
Chance of wetting rain:	
Tomorrow	
Maximum Temperature:	
Minimum RH:	
Winds (Slope/Valley):	
Winds (Ridegtop):	
Other Indices Used For Local Decisions	
Keetch-Byram's:	
Palmer Drought:	
1000-HR FM:	

Fire/Fire Surrogate Study

Fire Behavior Documentation Continued (FFS-Fuels-_) Date:____________

Study Site: _____________________________

Unit Identification: ________________________

Observers: _____________________________

Fire Behavior, Fire Weather, Supplemental Comments

Observation #	Time	Firing Technique	Rate of Spread	Flame Length	Fire Zone Width	Residence Time
Start						
End						

Observation #	Time	Dry Bulb	Wet Bulb	RH	Wind Speed	Wind Direction

Observation #	Time	Additional Comments:

Fire/Fire Surrogate Study **Date: ____ Study Site: _____ Unit: _____**

Grid Point Number: _______ **Transect Azimuth: __________**

Tallies			**Litter and Duff depth measurements (mm)**					
1-hr (0-¼") first 6 ft	**10-hr** (¼-1") first 6ft	**100-hr** (1-3") first 12ft	**At 12 ft.**		**At mid-way (25 ft)**		**End of transect (40 ft.)**	
			Litter	Duff	Litter	Duff	Litter	Duff

Height of down-dead woody material	@12-13 ft = _____in	@25-26 ft = ____in	@40-41 ft = _____in

1000-hr (3+") Fuels								
Diameter	**Species**	**Decay**	**Diameter**	**Species**	**Decay**	**Diameter**	**Species**	**Decay**

Grid Point Number: ______ **Transect Azimuth: _________**

Tallies			**Litter and Duff depth measurements (mm)**					
1-hr (0-¼") first 6 ft	**10-hr** (¼-1") first 6ft	**100-hr** (1-3") first 12ft	**At 12 ft.**		**At mid-way (25 ft)**		**end of transect (40 ft.)**	
			Litter	Duff	Litter	Duff	Litter	Duff

Height of down-dead woody material	@12-13 ft = _____in	@25-26 ft = ____in	@40-41 ft = _____in

1000-hr (3+") Fuels								
Diameter	**Species**	**Decay**	**Diameter**	**Species**	**Decay**	**Diameter**	**Species**	**Decay**

Grid Point Number: ______ **Transect Azimuth: _________**

Tallies			**Litter and Duff depth measurements (mm)**					
1-hr (0-¼") first 6 ft	**10-hr** (¼-1") first 6ft	**100-hr** (1-3") first 12ft	**At 12 ft.**		**At mid-way (25 ft)**		**end of transect (40 ft.)**	
			Litter	Duff	Litter	Duff	Litter	Duff

Height of down-dead woody material	@12-13 ft = _____in	@25-26 ft = ____in	@40-41 ft = _____in

1000-hr (3+") Fuels								
Diameter	**Species**	**Decay**	**Diameter**	**Species**	**Decay**	**Diameter**	**Species**	**Decay**

Fire/Fire Surrogate Study

Fuel Moisture Documentation (FFS-Fuels-_)

Unit Identification: ______________________

Study Site: ____________________________

Observers: ____________________________

	Sample Identification	Time	Bottle Number	Gross Wet Weight (gm)	Net Wet Weight (gm)	Gross Dry Weight (gm)	Net Dry Weight (gm)	Moisture Content (%)	Comments
Forest Floor Material By Layer (L, F, and H-layers)									
Woody material by size class (0-¼" and ¼-1")									
Live Fuel (note species)									

Fire/Fire Surrogate Study

Duff Pin Information (FFS-Fuels-_) Date: ____________________________

Unit Identification: ______________________ Study Site: ____________________________

Observers: ____________________________

Grid Point Number: ______

Transect Azimuth	**Pin Number**	**Surface Material Type**	**Duff Type**	**Distance from top of pin to remaining duff (mm) A**	**Depth of remaining duff (mm) B**	**Total Depth (mm) A+B=C**	**Comments:**
	1						
	2						
	3						
	4						
	1						
	2						
	3						
	4						

<u>Surface Material Type</u>:
BS – Bark slough
GR – Grass
MS – Mineral Soil
NS – No Surface Material
LM – Litter Material
UK – Unknown

<u>Duff Type</u>:
ND – No Duff
PW – Punky Wood
LD – F & H Duff