STUDY PLAN and ESTABLISHMENT REPORT

CONSEQUENCES OF FIRE AND FIRE SURROGATE TREATMENTS– THE OHIO HILLS SITE

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I. Introduction

Current forests in many fire-dependent ecosystems of the United States are denser and more spatially uniform, have many more small trees and fewer large trees, and have much greater quantities of forest fuels than did their presettlement counterparts (Mutch and others 1993, Agee 1994, Harrod and others 1998). Causes include fire suppression, past livestock grazing and timber harvests, and changes in land use (Bergoffen 1976, Dolph and others 1995, Arno and others 1997, Pyne 1982, Sutherland 1997, Yaussy and others 1997). The results include a general deterioration in forest ecosystem integrity and the threat of losing important, widespread forest types (Sutherland 1984, Clark 1993). Such conditions are prevalent nationally, especially in forests with historically short-interval, low- to moderate-severity fire regimes (Agee 1993, Yaussy and Sutherland 1994, Sutherland and Yaussy 1996, Kilgore and Taylor 1979, Taylor and Skinner 1998). This situation was addressed in the 1995 Federal Wildland Fire Management Policy Review and Report that contributed to the development of a new Federal fire policy. That policy directs Federal agencies to achieve a balance between suppression capability and the use of fire to regulate fuels and sustain healthy ecosystems.

In 1994, a team of scientists from the NE Station, Ohio State University, Ohio University, The Nature Conservancy, and the Ohio Department of Natural Resources Division of Natural Areas and Preserves initiated a project titled “Effectiveness of Prescribed Burning in the Ecological Restoration of Mixed-oak Forest Ecosystems in Southern Ohio” with support from USDA Forest Service Ecosystem Management Competitive Grants Program and substantial cooperation with the Wayne National Forest and Mead Paper Corporation. The research objectives of this project are to determine ecological response of mixed-oak communities in southern Ohio to prescribed underburning under two fire regimes (frequent and infrequent). The ecosystem management goals and applications are: 1) to determine appropriate prescribed underburning regimes as management tools in restoring the structure and function and much of the composition (fire-adapted flora) to the mixed-oak forests of southern Ohio, and 2) to design and implement a monitoring program of fire effects and ecosystem sustainability.

The ongoing research program includes: 1) Annual monitoring of vegetation composition and structure from the forest floor through the overstory layers, 2) Determination of woody plant sensitivity to damage and/or mortality by species and size (including analysis of the mode or mechanisms of damage: cambial vs. root mortality vs. leaf/bud loss); forest vigor and productivity, 3) Characterization of forest density, structure, regeneration, successional trajectory as well as aboveground productivity and nutrient dynamics, 4) Forest fire history from fire-scarred cross-sections, 5) Annual monitoring of soil organic matter quantity and turnover, forest floor composition, and nutrient status and cycling rates, 6) Key soil microbial population/functional group analyses, including bacterial and fungal population/activity levels and relative vesicular-arbuscular and ectomycorrhizal infection probability for tree seedlings, 7) Annual monitoring of composition, distribution, frequency, abundance, and age/stage structure of herbaceous plant species, with special focus on state and federally listed species, 8) Annual monitoring of faunal species composition, distribution, frequency, and abundance, with special focus on diverse taxa such as birds, herptiles, lepidoptera, and coleoptera, 9) Modeling of landscape level effects of fire, and other biophysical and historical factors with the potential to affect overall biodiversity, ecosystem health, or community fragmentation, 10) Historical patterns of fire weather, and prescribed fire weather predictions in Ohio. After five years of treatment and monitoring, the scientist involved felt that the overstory had not been reduced enough to allow adequate light to reach the forest floor to simulate the "open, park-like" conditions reported by early Europeans when traveling through the area.

In early January 2000, funding for a five-year "National study of the consequences of fire and fire surrogate treatments" (FFS) was awarded to a network steering committee representing 11 sites from the Pacific Northwest to southern Florida. The study was designed as an integrated network of long-term interdisciplinary research sites utilizing a common "core" design to facilitate broad applicability of results (Weatherspoon and Skinner, in press). The southern Ohio area was selected as one of the 11 sites. This study plan addresses research activities at the Ohio Hills site linked to the national FFS network.

II. Literature

The significance of the proposed research is that timely information will be provided to managers faced with sustaining the mixed-oak ecosystem that comprises almost one hundred million acres of forested land in the Central Hardwood Region of the Eastern United States. The type of information provided is also significant, because it will be grounded in a systemic understanding of the interactions among biologies, operational feasibility and economics. For a complete discussion of the rationale and importance of the study objectives and benefits of a successful study, see the full study plan for "Effectiveness of Prescribed Burning in the Ecological Restoration of Mixed-oak Forest Ecosystems in Southern Ohio" on file at the Delaware, OH, FSL, and the full FFS proposal and working plans on file at the Delaware, OH, FSL or at the URL: .

III. Objectives

Objectives of the FFS project are as follows:

1) Assess the extent to which treatments reduce fuels.

2) Determine operation production rates and economics, and identify the principal factors that explain them.

3) Determine the value of timber products removed.

4) Identify how different stand conditions and fuel loadings effect the economics of operations and the value of resources removed.

5) Assess how treatments directly influence residual tree damage or mortality, vegetation, soil structure, soil chemistry, the soil and litter food web, wildlife habitat, and disease populations.

6) Determine how treatment impacts on fuels, the chemical and physical properties of soils, and residual trees influence wildlife habitat and insect and disease populations.

7) Develop a matrix that identifies economic and environmental tradeoffs that occur among treatments.

IV. Methods

The Ohio Hills site of the FFS project is located on the Raccoon Ecological Management Area (REMA or Raccoon), and the Tar Hollow (TAR) and Zaleski (ZAL) State Forests in southeastern Ohio. The study is a complete randomized design of four treatments and three replications, resulting in 12 experimental units.

Treatments– The following suite of four FFS treatments will be implemented at each replication:

1) untreated control

2) prescribed fire only, with a second prescribed fire four years following the first

3) commercial thinning from below to 60 sq. ft. of basal area; no use of prescribed fire

4) commercial thinning from below to 60 sq. ft. of basal area followed by prescribed fire, with a second prescribed fire four years following the first

These four treatments span a useful range both in terms of realistic management options and anticipated ecological effects. Treatments 2, 3, and 4 will be guided by a desired future condition or target stand condition. The desired future condition is defined in terms of the tree component of the ecosystem and live and dead fuel characteristics. The following fire-related minimum standard served as a starting point for desired future conditions throughout the FFS network:

> Each non-control treatment shall be designed to achieve stand and fuel conditions such that, if impacted by a head fire under 80th percentile weather conditions, at least 80 percent of the basal area of overstory (dominant and codominant) trees will survive.

Hypotheses– Four common hypotheses for forest ecosystem restoration and management currently being discussed in the scientific and environmental conservation community relate directly to our four treatments:

Hypothesis A) Forest ecosystems are best managed by passive approaches, with no active manipulation of ecological processes such as fire, or forest structure such as by cutting, except for a continuation of fire suppression. Operationally this hypothesis leads to treatment 1, the untreated control.

Hypothesis B) Forest ecosystems are best managed by restoring ecosystem processes—i.e., by reintroducing frequent, low intensity fire. This hypothesis leads to treatment 2, the prescribed fire only treatment.

Hypothesis C) Forest ecosystems are best managed by restoring ecosystem structure—i.e., by using judicious thinning to restore density, species composition and spatial pattern of the tree component. This hypothesis leads to treatment 3, the thinning treatment.

Hypothesis D) Restoration of sustainable forest ecosystems requires both structural and process restoration. This hypothesis leads to treatment 4, the combined burning and thinning treatment.

From these general ecological hypotheses, we established specific hypotheses of how the ecosystem restoration treatments will effect the system and how that effect will change over time at the Ohio Hills Site, and selected actual core variables to measure that relate to the hypotheses:

Hypothesis 1) The three active treatments (fire, thin, thin/fire) will create distinctly different standing vegetation and down woody structure in the short-term (<5 years post-treatment).

Hypothesis 2) Disease will cause further divergence in standing vegetation structure among treatments in the intermediate term (5-10 years post-treatment) due to differences in vegetation mortality.

Hypothesis 3) The treatments will create different short-term responses in chemistry and the microbial food web of the soil and forest floor, which will lead to further divergence in standing vegetation structure for the intermediate term.

Hypothesis 4) Wildlife species will track changes in stand structure and down wood in the short term, and will diverge even more at later stages as a consequence of among-treatment divergence in standing structure and down wood.

The primary management objective of the Ohio Hills Site is reestablishing the stand structure characteristic which will sustain the mixed-oak ecosystem through prescribed burning and thinning from below. We assume that prescriptions written to obtain short-term structure objectives will result in the long-term large structure goal after several years, and that short-term structural objectives are the same regardless of whether fire or thinning is used. Fire and thinning have fundamentally different effects on the ecosystem, starting with the immediate effects on standing vegetation and down woody structure (Hypothesis 1). The first hypothesis will be tested by measuring a suite of vegetation and fuel variables including vegetation structure and composition, tree demographics, and both surface and vertical fuels. Post-treatment data on these variables will then be used to model oak sprout survival, fuel consumption, and immediate fire effects in the context of fuel moisture, seedling and sapling mortality, and species composition. We expect that stand structure will diverge further after a few years due to qualitative differences in how treatments influence the activities of below-ground ecology and disease (Hypothesis 2). Variables measured to test this hypothesis include bole scarring, ectomycorrhizae, crown condition, tree radial growth rate, and root disease incidence. The effect of fire on soils and the forest floor is expected to cause divergence in several measures of stand structure and composition (Hypothesis 3) through changes in stand productivity. Soil and forest floor variables that represent nutrient capital, available nutrients, nutrient cycling, physical properties, and biodiversity will be measured and compared. Values of these variables, especially in the short term, will be used to predict the suite of stand structure variables described for the test of Hypothesis 1. Modification of stand structure is expected to effect vertebrate species, through changes in habitat quality. Short-term structural modification will offer different opportunities for vertebrate species, and any structural divergence in the intermediate term is expected to change habitat quality accordingly (Hypothesis 4). Variables used to test Hypothesis 4 include small mammal species diversity and abundance, bird species diversity and abundance, bird nest productivity, and bird functional foraging responses. Since many bird species have home ranges larger than each treatment unit, interpretation of bird species diversity and abundance will also require information on the history, current treatment and current structure of the landscape surrounding each treatment unit.

The four hypotheses also establish a framework for an integrated analysis of the core variables. The first step will be the analysis of each response variable for post-treatment year 1, with treatment as the independent variable. We expect that active treatments will differ the least in standing structure, down woody structure and in wildlife variables, and the most in stand damage, soil, and activity fuel variables. These latter three variables, the result of different treatments, are expected to cause further divergence in stand structure in the intermediate term. Hence they will be used as independent variables (along with treatment) for analysis of effects on stand structure and wildlife in the intermediate and long term. While the primary test of hypotheses will consider the plot as the experimental unit in analysis of variance, the common sub-plot sampling grid will also allow regression analysis to establish linkages among variables at a smaller spatial scale. This will add insight on potential cause and effect relationships among variables, especially for the burn plots, where the treatment effect is expected to be particularly heterogeneous at the small scale.

Desired future condition—With our limited knowledge of the presettlement structure and condition of the forest, and the events leading to the development of the current forests of this area, our long-term desired future condition is a sustainable mixed-oak ecosystem in all moisture regimes in these stands. This includes less dense stands with 10 – 20% open sky; at least 50% of the overstory composed of oaks and hickories; oaks and/or hickories present on all moisture regimes; movement of oak and hickory stems through the sapling and pole sizes; no decrease, and possibly an increase, in floral, faunal and soil microbial biodiversity; nutrient cycles adequate to sustain a mixed-oak ecosystem; and an economical method to sustain these conditions.

Timeline— Site selection, and unit selections were completed by May, 2000 in collaboration with the Ohio Department of Natural Resources Division of Forestry and Mead Paper Corporation. Unit reference points and

50 m grid points were established by David Hosack, Louis Iverson, and Todd Hutchinson for all 12 units. All pretreatment measurements across all 12 treatment units were collected in the summer of 2000. Thinning in 6 units was initiated in September 2000. A prescribed fire burning plan will be written for 6 units and is planned for Spring 2001. First-year post-treatment measurements in all units is scheduled for summer 2001. Observations of birds will continue in 2002 and 2003. Complete reevaluation of all response variables in 2004 will complete the current funding cycle. These events are summarized in Table 1. Core variables, responsible individuals, and methodology for pretreatment measurements follow.

Table 1. Timeline of fieldwork activities at the Ohio Hills site, a site in the national FFS network

Season	**Activity**	**Personnel**
2000		
Spring		
	Site selection	Yaussy, Hosack, Karas, Boyles
	Paint boundaries	Hosack
	Establish grid points	Iverson, Hutchinson, Hosack
	Mark harvest	ODNR, Mead, NE
	Establish vegetation plots	Yaussy, Hosack
	Overstory bole examinations	Hosack
	Seeding evaluations	Hosack, McCarthy, Long, Hutchinson
	Sapling evaluation	Hosack, McCarthy, Long, Hutchinson
	Understory vegetation	Hosack, Hutchinson
	Forest floor and mineral soil sampling	Boerner
	N mineralization sampling	Boerner
	Begin litter bag incubations	Boerner
	Bird surveys	Miles
	Herpetofauna surveys	Miles
Summer		
	Fuel and CWD assessments	McCarthy, Riccardi
	Overstory crown examinations	Hosack, Long
	Identify *Armillaria* food bases	Long, Hosack
	Forest floor pathology sampling	Long, Hosack
	Aerial photography	ODNR
	Recover litter bag samples	Boerner
	Survey for exposed soils	Boerner
	Bulk density samples	Boerner
	Soil chemical analyses	Boerner
	Soil enzyme analyses	Boerner
	Bird surveys	Miles
	Herpetofauna surveys	Miles
	Mammal surveys	Miles
Fall		
	Harvest	Williams, ODNR, Mead
	Post-harvest fuels and CWD assessment	McCarthy, Riccardi, Hosack
	Chemical and physical soil analyses	Boerner
	Rhizomorph analyses of forest floor samples	Long, Rebbeck
	Survey thinned treatments for bole injury	Hosack, Long
2001		
Winter		

	Harvest	Williams, ODNR, Mead
	Chemical and physical soil analyses	Boerner
	Post-harvest fuels and CWD assessment	McCarthy, Riccardi, Hosack
	Pre-burn litter and duff assessments	McCarthy, Riccardi, Hosack
	Survey thinned treatments for bole injury	Hosack, Long
Spring		
	Prescribed burns	ODNR, NE
	Sapling and seeding evaluations	Hosack, McCarthy, Long, Hutchinson
	Understory vegetation	Hosack, Hutchinson
	N mineralization sampling	Boerner
	Begin litter bag incubations	Boerner
	Bury red maple stems for rhizomorph assessment	Long, Rebbeck
	Post-burn overstory bole examinations	Hosack
	Bird surveys	Miles
	Herpetofauna surveys	Miles
Summer		
	Recover litter bag samples	Boerner
	Survey for exposed soils	Boerner
	Bulk density samples	Boerner
	Second sapling and seedling evaluation	Hosack, McCarthy, Long, Hutchinson
	Post-burn overstory crown examinations	Hosack, Long
	Post-burn fuels and CWD assessment	McCarthy, Riccardi, Hosack
	Soil chemical analyses	Boerner
	Soil enzyme analyses	Boerner
	Bird surveys	Miles
	Herpetofauna surveys	Miles
	Mammal surveys	Miles
Fall		
	Third sapling and seedling evaluation	Hosack, McCarthy, Long, Hutchinson
	Forest floor pathology sampling	Long, Hosack
	Identify *Armillaria* food bases	Long, Hosack
	Collect red maple stems for rhizomorph assessment	Long, Rebbeck
	Chemical and physical soil analyses	Boerner
2002		
	Conduct red maple rhizomorph assessments	Long, Rebbeck
	Rhizomorph analyses of forest floor samples	Long, Rebbeck
	Chemical and physical soil analyses	Boerner
	Fuels and CWD assessment	McCarthy, Riccardi, Hosack
	Bird surveys	Miles
	Analyze data, forward to network, write mss.	All science cooperators
2003		
	Write mss., present results	All science cooperators
Spring		
	Forest floor and mineral soil sampling	Boerner
	N mineralization sampling	Boerner
	Begin litter bag incubations	Boerner
	Bird surveys	Miles
Summer		
	Recover litter bag samples	Boerner
	Survey for exposed soils	Boerner
	Bulk density samples	Boerner

	Soil chemical analyses	Boerner
	Soil enzyme analyses	Boerner
	Fuels and CWD assessment	McCarthy, Riccardi, Hosack
	Bird surveys	Miles
Fall		
	Chemical and physical soil analyses	Boerner
	Overstory bole examinations	Hosack
2004		
	Write mss., present results	All science cooperators
Winter		
	Chemical and physical soil analyses	Boerner
Spring		
	Seeding/sprout evaluations	Hosack, McCarthy, Long, Hutchinson
	Sapling evaluation	Hosack, McCarthy, Long, Hutchinson
	Place red maple stakes near food bases	Long, Rebbeck
	Bird surveys	Miles
Summer		
	Overstory crown examinations	Hosack, Long
	Seeding/sprout evaluations	Hosack, McCarthy, Long, Hutchinson
	Sapling evaluation	Hosack, McCarthy, Long, Hutchinson
	Bird surveys	Miles
Fall		
	Forest floor pathology sampling	Long, Hosack
	Survey food bases and off-plot trees for rhizomorphs	
	Collect red maple stems for rhizomorph assessment	
2005		
Winter		
	Rhizomorph analyses of forest floor samples	Long, Rebbeck
	Conduct red maple rhizomorph assessments	Long, Rebbeck
	Pre-burn litter and duff assessments	McCarthy, Hosack

Treatment and plot layout— Treatment units are whole, discrete stands or portions of larger stands all having irregular boundaries. Ten 20x 50 m plots were located within each treatment area across a moisture gradient identified within a GIS using an Integrated Moisture Index (IMI, (Iverson and others 1997)). Previous studies have shown a close relationship between IMI and plant associations ((Hutchinson and others 1999)). Grid points were established within a GIS in an ordinal orientation and transferred as waypoints to a GPS. Grid points were located on the ground with the GPS and marked with tagged pins and buried monuments. Maps of study areas and grid point locations can be found in the appendix. Table 2 provides the assigned treatment, unit size and number of plots for each unit.

Table 2. Treatment assignment, and initial conditions for 12 experimental units at the Ohio Hills Site, part of the national FFS network

Unit	**Block**	**Total Hectares**	**BA (m^2/ha)**	**Treatment**
REMA	1	28.8	23	Control

	2	29.5	22	Thin
	3	29.9	22	Thin/Burn
	4	26.8	19	Burn
TAR	1	31.3	22	Control
	2	33.7	20	Thin
	3	34.9	26	Thin/Burn
	4	32.9	21	Burn
ZAL	1	31.2	19	Control
	2	29.4	21	Thin
	3	26.3	21	Thin/Burn
	4	26.4	21	Burn

Core variables– A major aspect of the common design approved by the Joint Fire Science Program for the FFS project was a set of core variables to be measured at all network sites using common measurement protocols and a consistent within-unit sampling approach. The following represent core measurement variables for the network unless indicated otherwise. In general, the response variable of interest is the index represented by the difference between pretreatment and post-treatment value for a given variable summarized by treatment unit.

Vegetation

Hypotheses

A. Fire only treatment:

Overstory effects: We hypothesize that prescribed burning, alone, will have minimal effects on overstory mortality or quality. Fire will cause some bole injuries to species with thinner bark, but this will not adversely affect overstory oaks.

Sapling effects: We hypothesize that fire alone will have dramatic effects on sapling mortality depending on the severity of the fire, bark thickness, and tree diameter. Smaller trees will be killed due to the high fire temperature causing cambial death. Larger trees may not be killed quickly but may be infected by secondary organisms that result in tree death. Since most of the saplings in the study are *Carya spp.*, *Acer rubrum, A. saccharum, Nyssa sylvatica*, and others, substantial mortality is likely to be associated with fire alone.

Seedling effects: Seedling health will be negatively affected regardless of species. However, we hypothesize that the greater sprouting capability of oaks will give them a competitive advantage over maples, yellow-poplar, blackgum and other less desirable species, depending on seed crop dynamics.

B. Thinning only treatment:

Overstory effects: We hypothesize that thinning alone will have minimal effects on overstory mortality or growth. Thinning will likely result in an increase in bole injuries due to felling and skidding. These injuries will cause a degrade in quality and value

Sapling effects: We hypothesize that thinning will have moderate effects on sapling health that will be strongly related to the proximity of saplings to cutting and skidding operations. In some areas of the stand, saplings will be killed or severely injured by logging operations, but this will not extend throughout the stand.

Seedling effects: Thinning will affect seedling health only in areas affected by cutting and skidding activities. Some killed seedlings will sprout and recover, while in undisturbed areas, seedling health should be largely unchanged. Some seedling health and growth will improve as more light will be available.

C. Thinning and burning treatment:

Overstory effects: Depending on the fuels loading and fire intensity, thinning and burning could increase overstory mortality. We hypothesize that mortality will be limited (<2%) if burning can be done under desirable conditions. Some deterioration in overstory crown health could occur for those trees receiving injury from both thinning and fire treatments.

Sapling effects: Fire and thinning should have significant effects on saplings by causing cambial death of large numbers of stems, and by causing injuries sufficient to gradually kill others. Residual stems, depending on the severity of injury, may continue to deteriorate or may put on significant growth in the higher light environment produced by thinning. Since few oaks are present in the sapling class, the best result will be to kill most saplings.

Seedling effects: Fire and thinning will kill large numbers of seedlings. However, re-sprouting seedlings should respond vigorously and remain healthy due to the increased light conditions in the stand. This will affect both oaks and oak competitors such as red and sugar maples, yellow-poplar, blackgum and American beech. Without an additional fire treatment, seedlings emerging from the seed bank will lead to stand seedling composition conditions similar to those in the pretreatment period.

Methods

<u>Core Variables</u>

Overstory Vegetation

Stand structure and composition

Species

DBH

Status (live, standing dead by cause, dead and down, harvested)

Total height

Merchantable heights (pulpwood and sawlog)

Tree height to live and dead crown

Snag and log distribution

Product Age

Stand Function

Aboveground productivity

Sapling and Shrub Layer

Saplings

Species

Status (live, top-killed by cause, harvested)

DBH size class (small<3 cm; medium 3 - $\leq$6 cm; large >6 cm)

Shrubs

Species

Estimated % cover

Seedling and Understory Vegetation Layer

Tree seedlings

Species

Origin

Density

Shrubs and herbs

Species

Percent cover

Sampling Protocol

Data from all vegetation layers will be collected in the 120 permanent plots described in the experimental design. For most core variables, we will collect data in treatment years 0 (2000), 1 (2001), and 4 (2004), or funding years 1, 2, and 5.

Overstory vegetation (50 x 20 m plots)

Within each plot, all trees ($\geq$10 cm dbh) will be permanently numbered and tallied for species, dbh, crown class, crown condition, and mortal status in years 0, 1, and 4. Snags will be accounted for by a mortal status code indicating a standing dead tree. Heights will be measured on a sample of 10 trees in years 0 and 4 and for all trees marked for removal in year 0 (for use by the Economics and Utilization disciplinary area). Heights will be only measured pre-treatment and fourth year post-treatment. Aboveground age will be measured post-harvest in conjunction with the Utilization and Economics team. QA/QC procedures will consist of remeasurements throughout the study.

Sapling and shrub vegetation layer (3 10 x 10 m subplots)
In 3 randomly selected 10 x 10 m subplots per plot (Figure 2), we will record each sapling (>1.4 m height **-** <10 cm dbh) by species and dbh size class (small <3 cm, medium 3 **-** ≤6 cm; large >6 cm) in years 0, 1, and 4. From data in similar oak forests (Hutchinson et al., In Press), we estimate that sapling densities will average 50 small, 13 medium, and 6 large saplings per plot (300 m^2). For tall shrubs (>1 m height), we will estimate percent cover in the 3 subplots. QA/QC procedures will be preformed by randomly checking a subset of plots for data entry errors.

Tree seedlings and understory vegetation layer (1m^2 circular plots)

Tree seedlings
In each of 20 1 m^2 circular plots per vegetation plot (Figure 2), all tree seedlings will be recorded in three height classes: small (<10 cm), medium (10-50 cm), and large (50.1-140 cm), and into three status classes: first-year (germinant), established, and sprout. . From data collected in similar oak forests, we estimate a mean density of 136 seedlings per plot (Hutchinson et al. In Press). Quadrats will be permanently marked with steel pins. Seedlings will not be permanently marked. Sampling will occur in June, in years 0, 1, and 4. QA/QC procedures will be preformed by randomly checking a subset of plots for data entry errors.

Understory vegetation
In 12 of the 20 1 m^2 circular plots (3 randomly chosen along each plot “line”; Figure X), we will record the percent cover of all species into classes of <1, 1-10, 11-25, 26-50, 51-75, and >75**.** Previous work in similar oak forests in Ohio indicates that 12 1 m^2 plots will be sufficient to detect treatment effects on plant composition and diversity (Hutchinson et al. 1999). We will sample from late-May to late-June in years 0, 1, and 4. QA/QC procedures will include collection of unidentifiable plants in the field for later determination, separate teams of botanists will work together for several days to ensure proper species identifications, and we will randomly check a subset of plots for data entry errors

QA/QC procedures

Appropriate training will be given to all field crewmembers vegetation measurements. Previous research with similar or identical field crews showed that independent crews could reliably reproduce measurements on >

90% of the trees within ±1 measurement class. Unless otherwise specified above, QA/QC data will only be collected on overstory measurements if sufficient personnel and resources are available.

Pathology

Hypotheses

A. Fire only treatment:

Overstory effects: We hypothesize that prescribed burning, alone, will have minimal effects on overstory crown health and bole injury of target species. Fire will cause some bole injuries to species with thinner bark, but this will not adversely affect overstory oaks. Bole injuries could provide infection courts for wood decay fungi, but the time period associated with the study will prohibit conclusive study of whether this is a significant factor that could affect stand health and longevity.

Sapling effects: We hypothesize that fire alone will have dramatic effects on sapling health, causing injury, secondary infection, decay, and death depending on the severity of the fire, bark thickness, and tree diameter. Smaller trees will be killed due to the high fire temperature causing cambial death. Larger trees may not be killed quickly but may be infected by secondary organisms that result in tree death. Since most of the saplings in the study are *Carya spp.*, *Acer rubrum, A. saccharum, Nyssa sylvatica*, and others, substantial mortality is likely to be associated with fire alone.

Seedling effects: Seedling health will be negatively affected regardless of species. However, we hypothesize that the greater sprouting capability of oaks will give them a competitive advantage over maples, yellow-poplar, blackgum and other less desirable species, depending on seed crop dynamics.

Armillaria rhizomorph abundance: Fire should increase *Armillaria* rhizomorph abundance due to new food bases associated with fire-induced mortality of other species.

B. Thinning only treatment:

Overstory effects: We hypothesize that thinning alone will have minimal effects on overstory crown health and bole injury depending on the damage/injury associated with logging operations. Thinning will likely result in an increase in bole and crown injuries due to felling and skidding. These injuries will provide infection courts for secondary pathogens and insects, but depending on the incidence and severity of injuries/wounds will not affect long-term health of overstory trees.

Sapling effects: We hypothesize that thinning will have moderate effects on sapling health that will be strongly related to the proximity of saplings to cutting and skidding operations. In some areas of the stand, saplings will be killed or severely injured by logging operations, but this will not extend throughout the stand.

Seedling effects: Thinning will affect seedling health only in areas affected by cutting and skidding activities. Some killed seedlings will sprout and recover, while in undisturbed areas, seedling health should be largely unchanged. Some seedling health and growth will improve as more light will be available.

Armillaria rhizomorph abundance: Thinning will have a dramatic impact on *Armillaria* rhizomorph abundance by providing substantial new colonizable food bases in the form of stumps and downed woody debris. However, even though rhizomorph abundance may increase, if residual trees are not stressed by other agents (wounds, drought, insect defoliation), then they should not be adversely affected by the increase in rhizomorphs.

C. Thinning and burning treatment:

Overstory effects: Depending on the fuels loading and fire intensity, thinning and burning could have negative effects on overstory crown health and mortality. We hypothesize that mortality will be limited (<2%) if burning can be done under desirable conditions. Some deterioration in overstory crown health could occur for those trees receiving injury from both thinning and fire treatments.

Sapling effects: Fire and thinning should have significant effects on saplings by causing cambial death of large numbers of stems, and by causing injuries sufficient to gradually kill others. Residual stems, depending on the severity of injury, may continue to deteriorate or may put on significant growth in the higher light environment produced by thinning. Since few oaks are present in the sapling class, the best result will be to kill most saplings.

Seedling effects: Fire and thinning will kill large numbers of seedlings. However, re-sprouting seedlings should respond vigorously and remain healthy due to the increased light conditions in the stand. This will affect both oaks and oak competitors such as red and sugar maples, yellow-poplar, blackgum and American beech. Without an additional fire treatment, seedlings emerging from the seed bank will lead to stand seedling composition conditions similar to those in the pretreatment period.

Armillaria rhizomorph abundance: Fire and thinning should increase rhizomorph abundance due the large number of available food bases. *Armillaria* should act as additional thinning agent by killing weakened saplings and seedlings. *Armillaria* rhizomorph abundance will not have an adverse effect on the re-sprouting seedlings provided that other stressors (injury, drought, defoliation) are not significant.

Methods

<u>Core Variables</u>

The specific core variables for the pathology research have been largely derived for coniferous forests and most of the protocols have limited application for hardwood oak forests in Ohio. The specific variables to be sampled will be described for the following major components:

Overstory crown health

Live crown ratio

Crown vigor class

Percent crown dieback

Percent defoliation

Overstory bole injury/defect

Injury/defect type

Open or closed condition

Location on bole

Sapling health

Initial diameter

Vigor class

Percent crown dieback

Percent affected by herbivory/disease/injury

Seedling/sprout health

Initial basal and root collar diameter

Crown shape

Leaf number

Leaf color

Leaf size

Percent crown dieback

Percent affected by herbivory/disease/injury

Armillaria root rot abundance and vigor

Rhizomorph frequency and mass in the forest floor

Rhizomorph abundance on food bases (standing dead trees, stumps, large woody debris) Rhizomorph abundance around living *Quercus* root collars

Armillaria vigor: estimated by rhizomorph colonization of red maple stems

Sample Protocols and Field/Laboratory Methods

Overstory crown health

All overstory trees (trees ?10 cm dbh) within each of the ten 1000 m^2 plots in a treatment area will be evaluated in July or early August in year 0 (pretreatment) year 1, and year 4 by two trained raters. Crown vigor will be rated on a 6 class scale (where 1=healthy tree and 6=dead tree) following the protocols and definitions of the North American Maple Project (NAMP) (Cooke et al. 1997). Percent crown dieback and defoliation are estimated as separate variables and will be rated in a 6 class system where:

0	no or trace dieback present
1	<10% crown dieback
2	10 to 25% dieback
3	26 to 50% dieback
4	51 to 75% dieback
5	76 to 100% dieback

For crown dieback, only branches with small twigs <2.5 cm diameter are rated. Snag and large branches with no fine twigs are assumed to have died earlier and are only rated in the vigor estimate. The identical rating scale as above was used for estimating defoliation as the amount of foliage removed by chewing insects or foliar pathogens. For all measurements two observers stand on opposite sides of the tree crowns and must agree on the rating.

Overstory bole injury/defects

In each 1000 m^2 plot, the first 20 trees (in thinned treatment plots the first 20 non-cut trees) were evaluated for bole injury. Starting on the upslope side of the tree, each tree was divided into quadrants, and rated by quadrant in a clockwise direction to a height of 244 cm (8 feet). Four wound types to be identified by the raters were: 1) crack or seam exceeding 30 cm in length, 2) wounds, defects, or cankers exceeding 25 square cm in area, 3) branch stubs over 5 cm in diameter at the point of attachment, 4) butt swell in the lower one meter of the bole, and 5) small wounds if they readily meet the 25 square cm threshold. Additionally, observers recorded whether the wound was closed over with bark or had exposed (open) wood. The height to the approximate center of the wound to the nearest 0.5 m was also recorded. A total of 2400 trees will be evaluated for bole wounds.

Boles of trees in thinned treatment units will re-evaluated after thinning in fall-winter 2000, but before fire treatments in spring 2001. For burned plots an additional bole injury/defect evaluation will be conducted in May-June 2001 after the prescribed fire. The amount of the basal bole circumference charred by fire will be evaluated and estimated as: 0 to trace, <25%, 26-50%, >50%. In addition, the height of the charring will be estimated and recorded. The subsequent post-treatment evaluations will focus on determining probable causal organisms associated with tree health and mortality and whether these organisms were primary or secondary agents. All 2400 trees will be evaluated again in year 4.

Sapling health

For the sapling and seedling pathology research, only 9 of the 10 plots in each treatment area were used (total = 108 plots). This was done due to logistical and personnel limitations. To determine the plot to be dropped in a treatment area, integrated moisture index values were examined and a plot with a value that was redundant or nearly redundant was dropped. The dropped plots were: Z108, Z209, Z302, Z407; T107, T205, T305, T407; R106, R205, R305, R406. In each 1000 m^2 plot, 10 saplings will be selected across the plot with the exception that subplots 2 (reserved for regeneration and demography research) and 4 (reserved for soils research) will not be used. Saplings (stems >1.4m tall and <10 cm dbh) will be selected to favor species of interest which include oaks, hickories, red maple or yellow-poplar. Each sapling will be tagged, mapped, and the dbh recorded. The saplings are further subdivided into small, <3 cm dbh stems, medium, 3 to 6 cm dbh stems, and large, 6.1 to 10 cm dbh stems. A range of size classes will be evaluated. Health evaluations for the medium and large saplings include vigor (6 class system used with overstory trees), percent fine twig dieback, and percent herbivory/disease/injury, using the same scales described above for overstory trees. Additionally, the stems will be examined for wounds and injuries. Wounds and injuries will be noted as longitudinal cracks or wounds and whether the crack or wound is covered with bark or has exposed wood. Health evaluation protocols for small size class saplings, those <3 cm dbh, will be identical to those used for seedlings (described below). A total of 1080 saplings will be evaluated in the study. Dying saplings will be evaluated to determine probable causal agents and, if sprouting occurs, the number and vigor of new sprouts. New sprout vigor will be evaluated as described below for seedlings. Sapling evaluations will occur during June and July for year 0 (pre-treatment), year 1, and year 4.

Seedling/sprout health

Seedling/sprout health also will be evaluated for 10 seedlings identified in each of the 108 plots. Species selection will favor *Quercus* and *Carya spp.* when possible. No seedlings occurring in subplot 2 will be used. Initial basal diameter and, if present, root collar diameter will be measured and recorded along with seedling height to the terminal bud. Seedling health and vigor will be evaluated using methodology described by Gottschalk (personal communication) and Carvell (1967). These measures include:

Stem origin: seedling or sprout
Crown shape: normal, flat-topped, flat-topped with major fork
Number of leaves: <10; 10-25; 26-50; 51-100; >100
Leaf color: normal; light green between veins; chlorotic; brown edges and tips
Leaf size: large, >15 cm long; medium, 10-15 cm long; small, <10 cm long
Percent fine twig dieback, using same scale as for overstory trees.
Herbivory/disease: percent foliar damage from insects and/or pathogens

Starting in year 1 in thinned plots, sprouts from selected oak and/or hickory stumps will also be evaluated. Numbers of stems evaluated will depend on logistical and resource limitations. The tallest sprout on each stump will be marked and monitored. Seedlings/sprouts will be evaluated in June of year 0 (full rating). In year 1, seedlings will be evaluated in early June (full rating), in late July/early August and in early September, but only to record mortal status. After prescribed burning, new sprouts will be identified and evaluated. During seedling/sprout evaluations if pathogens or insect problems are obvious, seedlings/sprouts with similar symptoms from off-plot locations will be destructively sampled to determine probable causal agents. In particular, efforts will be focused on determining organisms associated with seedling/sprout mortality.

Armillaria abundance and vigor

Armillaria root rots are among the most important secondary mortality agents in oak forests. *Armillaria* typically grows in close association with living roots, but is unable to successfully challenge and infect roots until stress-induced biochemical changes occur. Food base assessments will be conducted in four randomly selected and temporarily located 10 m by 10 m subplots outside but adjacent to the established subplots in the 108, 1000 m^2 plots. Potential food bases will be examined for the presence of *Armillaria* rhizomorphs. Food bases, in the order of priority for examination, include standing dead trees =15 cm dbh, intact stumps =15 cm diameter, and large down woody debris in contact with the forest floor and =15 cm in diameter. Food bases will be examined for the presence of rhizomorphs, whether the rhizomorph(s) is firmly attached, whether mycelial fans are present, and whether pockets of decay typical of *Armillaria* are present. In addition to the food base assessment, a living oak tree in one of the 4 temporary subplots will be examined for the presence of *Armillaria* rhizomorphs. A Pulaski will be used to carefully remove the litter and associated mineral soil about 15-20 cm from the bole/soil line and proceeding around the bole of the tree. The bole will be divided into quadrants and *Armillaria* rhizomorphs are rated as absent, scarce to light, moderate, or heavy in each quadrant. For all *Armillaria* research only the nine plots used for the seedling/sapling health evaluations were used (108 plots total). This provides a total of 432 temporary subplots in which food base colonization will be assessed and a total of 108 living oak trees that will be used for assessment of *Armillaria* rhizomorphs. This will be repeated in years 1 and 4, but with new randomly selected temporary subplots that are adjacent to the marked 1000 m^2 plot.

To assess *Armillaria* frequency and abundance in the forest floor, samples approximately 15 cm by 15 cm by 10 cm deep will be obtained near the center in 3 of the 4 temporary subplots in year 0. The sample is taken by placing a template on the forest floor and cutting with a knife around the periphery and into the forest floor and mineral soil. A shovel is then used to gently remove the sample and place it in a ziplock plastic bag. The distance of the forest floor sample to the nearest food base is also recorded. Previous research indicates that samples taken within 1-2 meters of a food base have a much higher probability of yielding rhizomorphs (Twery et al. 1990; Marcais and Wargo, *in press*). Samples will be taken in late summer or fall of the pre-treatment year and kept at about 5°C until processed. Each sample will be dissected and rhizomorph segments will be separated from soil and roots and their length and total dry weight will be determined. This sampling will be repeated in year 1 and in year 4.

Armillaria vigor will be assessed by determining the ability of the fungus to colonize recently cut red maple (*Acer rubrum* L.) stem sections buried in the soil. At 1-3 locations per plot where rhizomorphs were recovered in year 0 from forest floor soil samples adjacent to food bases, 2-3 stem sections of red maple, 15 cm long and 2-3 cm diameter, will be placed in the soil in June of year 1. The forest floor will be lifted and intact rhizomorphs in the soil will be located and attached to maple sections with twist ties. The maple sections will rest on mineral soil and will be covered with forest floor and left for approximately 90 days. Maple sections will then be relocated and the initial rhizomorph will be cut from the network while leaving new rhizomorphs formed on or around the section intact. Maple stem sections will be returned to the laboratory and stored at 5°C until processed. In the laboratory, the presence of new rhizomorphs formed on sections, and the presence of *Armillaria* mycelial fans in the cambial area of the maple stems (Marcais and Wargo, *in press*) will be determined. Isolations from rhizomorphs will be grown in culture and used to identify species of *Armillaria*. This will be repeated in year 4.

QA/QC procedures

Appropriate training will be given to all field crew members on crown and bole health evaluations. Crews will work in pairs and must reach agreement on crown ratings. Previous research with similar or identical field crews showed that independent crews could reliably reproduce measurements on > 90% of the trees within ±1 measurement class. For this reason, QA/QC data will only be collected on overstory measurements if sufficient personnel and resources are available. Likewise, if resources are sufficient, bole wound/injury assessments will be repeated on a 5 to 10% sub-sample of trees with the goal of identical frequencies of wound/injury types on at least 75% of the trees in a plot.

QA/QC procedures used for seedling and sapling health evaluations will focus on careful training. Since most of the plots will be re-visited on successive occasions in years 0 and 1, there will be substantial internal QA/QC and re-measurement and re-assessment of seedling and sapling health status. Crews will be given appropriate training and will work with an experienced scientist in the initial stages of the research. If possible, approximately 5% of the plots will be re-measured. Crown vigor, dieback, defoliation, crown shape, number of leaves, leaf color, leaf size, and percent herbivory/disease should not differ more than ±1 class on 90% of all seedlings or saplings.

Armillaria food base sampling will be preceded by thorough training for the field crew. Re-measurement will not be practical since food bases are not tagged. Since most of the data collected involves assessments plus or minus assessments (presence/absence, firmly attached/not firmly attached, etc.), there is not as much subjective judgment. Careful training of field crews will be the major QA/QC activity.

Soil and Forest Floor Disciplinary Area

Hypotheses

A. Fire only treatment: We hypothesize that prescribed burning, alone, will result in consumption of 40-80% of the unconsolidated leaf litter and associate fine woody fuels. This will alter the forest floor surface in such a manner that the soils will warm up earlier in the spring and dry down earlier during the usual mid-summer dry period. In addition, maximum and minimum soil temperatures and moistures will be greater in the burned plots than in controls. Burning is not expected to affect soil texture, strength, or compaction. Prescribed fire will increase surface soil pH, base saturation, inorganic N and P concentrations, and both N mineralization and nitrification, with those effects being more pronounced in intermediate landscape positions than in dry or mesic ones. Effects on soil biodiversity are expected to be transient, and microbial activity should initially increase after a single fire.

B. Thinning only: We hypothesize that thinning will result in a large increase in coarse and fine woody debris, with an associated increase in spatial heterogeneity. In areas with large debris deposits, soils will warm later in the spring and dry down later in the summer. Soil texture will not be affected, though soil strength and compaction are expected to increase overall and in spatial heterogeneity. Soil pH and base saturation may increase slightly due to leaching from newly deposited debris and reduced uptake. Available N in the soil solution, N mineralization, and nitrification are all expected to increase due to microclimate alteration and changes in uptake. Soil biodiversity may be affected depending on the distribution and amount of debris, and microbial activity should initially increase.

C. Thinning and Burning: We expect the intensity of the fire in the thinned plot to be greater than that in the burn only plot, due to greater fuel and possibly to lower fuel moisture. Effects on soil physical properties are expected to parallel those of the thin only plot, whereas effects on soil chemical and biological parameters are expected to parallel those in the burn only plot but at greater magnitude.

Methods

<u>Core Variables</u>

The specific core variables that will be sampled in order to meet the needs of this disciplinary area will be:

- Forest floor and soil organic matter and nutrient capital
  - Litter mass (L+F)
  - C, N in composited L+F
- Mineral soil chemistry

C, N

macronutrients and pH

Soil Nutrient Availability

Nitrogen mineralization in forest floor and mineral soil

Nitrification in mineral soil

Soil Physical Properties

Bulk density of the top 20 cm

Exposure of mineral soil

Soil Biodiversity Assessment

Soil Enzyme Activity

Soil Micro-arthropods

Initial Site Characterization

Standard morphological and taxonomic survey methods

Texture

Sample Protocols and Field/Laboratory Methods

We anticipate measuring all the soil and forest floor core variables during the pretreatment year, the immediate post treatment year, and one additional year as late in the project period as possible. As our site is one in which thinning and burning can be done within the first 1.5 yr of the project, this will translate to samples taken during years 0, 1, and 3 (in terms of treatment years), or years 1, 2, and 4 (in terms of funding years).

At the network scale, it was agreed that the spatial pattern of the soil and forest floor sampling will be guided by the design of the subplots for vegetation analysis, whereas the degree of replication within and around each subplot will be determined by the magnitude of underlying variability in each site. In our study site, the overall site team has agreed that one of the ten subplots within each of the ten sample plots will be set aside for sampling of soil and forest floor for both this disciplinary area and for the pathology team. We will sample within that subplot and supplement, where needed, with samples taken outside the larger vegetation plot.

To determine the C and N content of forest floor, we will take six samples per plot, with two coming from the subplot and four from the corners of the larger 0.1 ha plot. Sampling will take place in May of each year. Prior studies in the region have confirmed that such sampling intensity is sufficient to account for spatial autocorrelation among samples and spatial components of variance (Boerner et al. 1998)

As our sites typically lack a continuous, well defined, easily differentiated humus layer common in many conifer forests, we will sample the unconsolidated litter and fragmented layers as a single unit. A steel 15 cm X 15 cm X 10 cm forest floor sampler will be used to obtain these samples and they will be returned to the laboratory in paper bags. Forest floor samples will be dried at 70C to constant weight and then weighed to determine total forest floor mass.

After drying and weighing, the six samples of the forest floor will be composited into two composite samples, one consisting of the four corner samples and the other of the two samples from the subplot. Subsamples of these composite forest floor samples will be analyzed for C content by Walkley-Black oxidation/titration (Nelson and Sommers 1982). Subsamples will also be digested in H_2SO_4:H_2O_2 and analyzed for total:N by colorimetry on a BioTek Microplate Reader. Methods will follow those presented in Morris and Boerner (1998a, 1998b) for use in this region. Should the use of an automated C:N analyzer would become available to us, we will switch our analysis to this instrument. The methods used in a C:N analyzer protocol preferable to the methods we propose, as automated analysis is, in the long run, cheaper, produces less toxic waste and is safer for lab personnel. However, cost constraints have eliminated the purchase of an automated C:N analyzer as an option.

Mineral soil will also be sampled for C, N, and macronutrient content using the sample protocol and timing indicated above for the forest floor. Total C and N in mineral soil will be analyzed as above as well. Mineral soil samples will be extracted for Ca, Mg, and K with 1M NH_4OAC (Thomas 1982), for Al and P with 0.5M K_2SO_4, (Olsen and Sommers 1982). Cat-ion analysis will be done by atomic absorption spectroscopy, and P analyses by stannous chloride/molybdate colorimetric method. Soil pH will be determined in a 1/5 w/v slurry. Previous studies in this site have demonstrated that sampling the uppermost 20cm of the A_1 horizon is sufficient to characterize the chemical and physical characteristics of the soils) (Riemenschneider 1964).

Analysis of nutrient availability (i.e. N mineralization and nitrification) will be done for during mid-May to mid-June of each year using aerobic, *in situ* incubations for measurement of N mineralization and nitrification. This sampling timing corresponds to the early season peak in plant growth and microbial activity. The methods are described in more detail by Plymale et al. (1987). Analysis of N mineralization and nitrification by this method involves the following field steps: (1) taking composite soil samples from the dedicated subplot, (2) sieving the soils through a 6 mm screen to remove stones and roots, (3) placing aliquots of 50-80 g of the sieved soil into several polyethylene bags and returning them to the hole from which the sample came for a 20-30 day *in situ* incubation, and (4) returning the remaining sieved soil to the laboratory for immediate K_2SO_4 extraction (Keeney, and Nelson 1982) for subsequent analysis of NH_4 and NO_3 concentration. We will incubate 3-4 bags at each point. Multiple bags at each point are necessary as soil fauna may burrow into or out of individual bags, thus rendering them useless. Prior studies in these sites indicate that placing 3-4 bags at each site safely ensures 1-2 intact samples post incubation (Plymale et al. 1987). After 20-30 days, the samples which have remained *in situ* in the polyethylene bags are recovered and extracted for inorganic N the same way. Net N mineralization is calculated as the difference in total inorganic N (NH_4+NO_3) between the initial samples and those incubated *in situ* for 20-30 days. Proportional nitrification is calculated as the net difference in NO_3 concentration between the initial and incubated samples divided by the total NH_4 available for nitrification (i.e. initial NH_4 + net N mineralization). See Eno (1960) for further details on this method.

Each plot will be searched every July for areas of exposed mineral soil greater than 400 cm^2 in area using methods modified from those developed at Hungry Bob. Each summer we will establish a transect parallel to and just upslope of the long axis of each 0.1 ha vegetation plot. Along this transect we will select 20 random points at distances of 1-3 m. At each point penetrometer readings of soil strength of 15cm will be taken and the condition of a 1m2 circular plot surrounding that point assessed using the categories listed in Table 3.

Table 3. Surface disturbance classes used to assess physical soil disturbance at the Ohio Hills Site

Class	Category	Description
0	Undisturbed	Soils undisturbed and considered to be in a natural state. Vegetation present with well-established root systems. No evidence of past equipment operation.
1	Slight	Site in virtually undisturbed. Vegetation present or redeveloping with well-established root systems. Organic layers intact. Surface soil intact and uncompacted. Impressions of wheel tracks may be present.
3	Moderate	Vegetation present or redeveloping. Old organic layers partially intact or missing; new litter layer developing. Surface soil intact but puddled and/or compacted. Wheel tracks or cleat marks evident.
4	High	Vegetation shows signs of stress. Organic layer removed. Surface soils partially or totally removed, or may be mixed with subsoil. Some evidence of blading, gouging, or turning.
5	Severe	

Vegetation restricted or severely stunted. Organic layer removed. New litter layer redeveloping or absent. Surface soil absent. Subsoil exposed, compacted, or removed. Evidence of excessive blading and gouging. Hydrology affected.

Using these methods, soil exposure at the plot level will be considered the proportion of transect points classified 3 or higher divided by the total number of points per plot. Similarly, the proportion of the soil that will be considered uncharacteristically compacted is the number of transect points with penetrometer readings greater than 150% of the median for that plot determined in the pretreatment sampling divided by the total number of penetrometer readings per plot. Total soil disturbance (%area disturbed) is the number of exposed plus compacted points minus points in which both disturbances have occurred, divided by the total number of assessed points per unit.

The primary method used for biodiversity analyses will be a suite of soil enzyme activity determinations, paralleling similar studies done as part of our larger prescribed burning-ecosystem management research program for the last six years. Each August/September samples will be taken from three places within the dedicated subplot of each sample plot and analyzed for the activity of acid phosphatase, phenol oxidase, and chitinase using p-nitrophenyl-linked substrates and spectrophotometric methods (Decker et al. 1999, Boerner et al. 2000a). Previous studies in the region have demonstrated that late season sampling for enzyme activity reduces within-plot variability and maximizes the probability that among-plot treatment effects can be resolved (Boerner et al. 2000b).

Each site is also responsible for a secondary method for biodiversity analysis that is to be done on a subset of the sample plots. Our secondary method will be the assessment of the abundance and diversity of soil micro-arthropods, particularly mites and springtails. We will choose one of the three study sites for this secondary analysis. Within that study site, six cores (20 cm length, 10 cm diameter) will be taken from the dedicated subplot within each 0.1 ha sample plot (total of 60 cores). Microarthropods will be extracted by Berlese funnel and enumerated by direct count microscopy.

QA/QC

QA/QC of laboratory analyses will be ensured by performing duplicate analyses on 10-15% of the samples, with sample labeling done in a manner that prevents the analyst from knowing which samples are duplicates. Results from duplicate samples will be accepted if the proportional difference between them is <20% of the difference between the results of those duplicate samples and those from spatially-uncorrelated samples in the same IMI class and treatment unit. QA/QC for field determinations (e.g. penetrometer readings and soil disturbance ratings) will be ensured by having independent, duplicate assessments done by two field crew members on 5% of the sample points.

Initial soil characterizations of all 120 sample plots will be done during year 0. An intact core (10 cm diameter, 50 cm length) will be extracted next to each 0.1 ha sample plot. The intact core will be placed on a white background and soil color determined using a Munsell soil color chart for reference. Horizon depth, color, structure, and other visual factors will be recorded in the field. Samples will be returned to the lab and analyzed for texture using the hydrometer method. Soils will be classified using Natural Resource Conservation Service county soil manuals for reference. The reference soil collection at the Ohio State University will be consulted to resolve problematical classifications.

Fuels and Fire Behavior

The primary goals of the fuel and fire behavior analysis are to characterize the changes in fuel loading resulting from fire and fire-surrogate treatments at each research site, and to document fire behavior during the fire treatment applications. Ground and surface fuels will be measured before and after treatment and at specified times throughout the length of the study. Understory and overstory fuels will be recorded by the vegetation team. Based on previous observations, understory & overstory fuels rarely contribute much to fires in southern Ohio, but the addition of fuel and subsequent burning in one treatment may alter this. In addition, fuel moisture content, fire behavior measurements, and fire weather data will be collected at the fire treatment application sites.

Hypotheses

A. Forest ecosystems are best managed passively, with no active manipulation, allowing natural processes to take place. This gives rise to the untreated control in this experiment.

B. Forest ecosystems are best managed by restoring natural disturbance regimes, i.e., reintroducing low intensity fires. This hypothesis leads to the prescribed fire treatment.

C. Forest ecosystems are best managed by restoring ecosystem structure; i.e., by manipulating species composition, density, and spatial patterns of the constituent trees. This hypothesis leads to the periodic cutting treatment.

D. Restoration of sustainable forest ecosystems requires both structural and process restoration. This hypothesis leads to the combined burning and cutting treatment.

From these general ecological hypotheses, we establish *specific* hypotheses of how the active treatments will affect the system and how that affect will change over time:

Hypothesis 1: The three active treatments and untreated control will exhibit distinctly different fuel loads (*fuel quantity*) in the short-term (< 5 yrs).

Hypothesis 2: The three active treatments and untreated control will exhibit distinctly different fuel structures (*fuel quality*) in the short-term (< 5 yrs).

Hypothesis 3: Changes in short-term fuel quantity and quality will influence fire behaviors.

Hypothesis 4: The active treatments will differentially promote the regeneration of certain hard-wood species (e.g., oak).

Methods

Surface Fuels

NB: All field methods follow the general protocol established by Ottmar and Haase.

Ground (litter and duff) and surface fuels (fine and coarse woody debris) will be measured before and after treatment and at specified times throughout the length of the study. Understory and overstory fuels (live and standing dead saplings and trees) will be recorded by the *vegetation team*. The specific fuel variables to be measured are listed in Table 4.

Table 4. Specific fuel variables to be measured

Ground fuels	L-layer (newly cast litter), F-layer (litter beginning to break down yet still identifiable) H-layer (humus consisting of unidentifiable organic material)
Surface Fuels	Coarse woody debris Ground-level plant biomass
Understory Fuels	Live and dead shrub and sapling biomass
Overstory Fuels	Standing live and dead biomass of trees and tall shrubs Vertical and horizontal distribution of overstory fuels
Fire Behavior	

Fuel moisture
Fire weather
Flame length
Rate of spread
Smoldering duration

In southeastern Ohio, the fires are often very heterogeneous and patches of ground fuels remain unburned following many fires. Where the litter is consumed, the L- and F-layers will contribute most significantly to fire behavior in the fire treatments. Consumption of the H-layer is uncommon given the rate of spread, moisture, and temperatures, but will be measured because of its potential below ground consequences. Thus, the mass of the ground fuel component will be measured or accounted for on each treatment plot.

The amount of forest floor material will be determined by destructively sampling the forest floor material and developing a regression equation relating forest floor mass to forest floor depth. Being able to use this indirect method of predicting forest floor weight allows the use of duff spikes to estimate forest floor mass in the burn treatment plots both before and after a fire with less disturbance in sensitive areas where such disturbance may affect fire behavior.

Samples used to develop the prediction equation are randomly selected (near the ends of the fuel sampling transects, Figure 3) in areas that have the full range of forest floor depth on the plot. If blocks are used in the design of the study site, a different predictive equation may be necessary for each block if there appears to be significant differences. Seventy-two samples (each 1000 cm^2; 2 for each of 36 grid points) will be used to develop the prediction equations. Each sample will be collected by layer (L, F, and H) and bagged separately. A depth for each layer will be measured in the center of each side of the square sample and the depths are then averaged for that sample.

The amount of forest floor material removed by prescribed burning is critical for defining vegetation and soil responses as well as smoke production potential. A series of eight duff pins (two groups of four) will be used to determine the amount of forest floor material removed during the burns. The eight steel pins will be located on perpendicular axes located at the end of each sample transect and marked with pin 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 and recorded. The total distance from the top of the pin to mineral soil is also recorded for each pin. These measured depths are then applied to the prediction equation to estimate the tons per hectare of forest floor material present and what amount is removed by burning or other treatment.

Destructive sampling will be required to characterize the forest floor on the plots receiving thinning due to the high level of physical disturbance the thinning may produce. It will also be necessary to destructive sample forest floor material on the control plots. The destructive forest floor samples will be taken in conjunction with the woody fuel transects. The down dead woody fuels will be measured using Brown's (1974) planar intercept method. Fuel will be classified by size class (0-6 mm, 6-12 mm, 12-25 mm, 25-75 mm, and >75 mm), decay class condition (sound or rotten), and the number of intercepts and diameters of >75 mm diameter material by species (Figure 3). This fuel inventory will need to be done prior to treatment application, after thinning activity is completed and after the application of the prescribed fire treatments. The fuel inventory will be collected on two 20 m transects originating from each of 36 grid points centrally located in the treatment unit. This will result in 1440 m of transect sampling per unit (5,760 m per site). A pre-treatment sample of all units will thus constitute 17,280 m of fuel transect sampling. Because the fuels must be re-sampled in the thinning treatment units (half of units) after treatment execution, this adds an additional 8,640 m of transect. Resampling following the burn treatment (half of units) again adds 8,640 m of transect sampling resulting in 34,560 m of sampled fuel transect for the study. Each of the 20 m transects will be permanently marked with wire flags and a bolt in the ground for relocation with a metal detector (constant azimuth headings will be used to assist relocation). The same transect will always be measured before and after treatments.

At this site, herb biomass does not substantively contribute to ground fires, but greenbrier often does and has an important effect on fire behavior and effects. The greenbrier will be destructively sampled before and after the burn treatment.

The overstory fuels are important in estimating fire risk and crown fire potential on a site. Species, tree density, diameter at breast height, ladder fuel height, number of canopy layers, height to live crown, total height, and percent canopy closure are critical variables and are needed to calculate fire risk and crown fire potential. These variables will be changing during the applications of the treatments within the study. The collection of these data will be part of the basic vegetation sampling and will be incorporated into the overstory plot descriptions for each plot and subplot.

Samples for the measurement of 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. Woody fuel moisture content samples will be collected by size class. Moisture content must also be determined for the live fuel component. This will be done by vegetation class (grass, forb and shrub) and will be sampled to represent the entire plot. The moisture content is determined on an oven dry basis. This information will be collected by the burning crew.

It will be necessary to document fire behavior at each burn treatment plot to be able to qualify the fire intensity between fire treatment plots. Flame length will be measured as an ocular estimate on the flame front. Rate of spread is estimated by timing the movement of the flaming front to cover a known distance. This will be done for both heading and backing fire fronts. 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 visually 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.

Coarse Woody Debris

The sampling protocols developed for estimating large woody material for fuels management are not adequate for describing the structural aspects of coarse woody debris (CWD) for wildlife purposes. For example, estimating the percentage of ground covered by logs may be an important variable relating to the abundance of small vertebrates and their food resource. Length, diameter, and decay class are important aspects of CWD required by some wood boring insects and salamanders.

We have employed similar protocols for the determination of CWD as proposed in the FFS plan. Sample plots will be established on the same 36 grid points in each unit that are used for fuels sampling (the same team will collect these data). A 4 ´ 20 m strip plot will be centered on one of the two 20 m transects used for fuels sampling at each grid point. Within each strip-plot only logs or parts of logs that are at least 1 m in length and have a large end diameter 15 cm or greater will be measured and counted. The small end (> 7.62cm) and large end diameters will be measured on all qualifying logs or parts of logs that fall within the boundaries of the strip-plot. If a piece extends outside the strip-plot, diameters are measured at the line of intercept of the strip-plot boundary and CWD piece. Piece lengths are the lengths of the CWD within the strip-plot area and are recorded. The length of the entire piece must be measured to determine the midpoint of the CWD. If the midpoint is within the strip-plot, the piece is given an additional rating of “1’’ for the Indicator Variable. If the midpoint falls outside the strip-plot the piece is given a rating of “0’’ for the Indicator Variable. In addition the species (if possible) and decomposition class of each log will be recorded. The following 5 log decomposition classes will be used to rate the CWD (from Thomas 1979):

Decomposition class 1: bark is intact; twigs are present; wood texture is intact; log is round; original wood color; log may be elevated on support points.
Decomposition class 2: bark is intact; twigs are absent; wood texture is sound or becoming soft; log is still round; original wood color; log elevated on support points but sagging slightly.

Decomposition class 3: bark has fallen off; twigs are absent; wood texture is hard; log is still round; original color of wood is faded; log is sagging near ground.

Decomposition class 4: bark is absent; twigs are absent; texture of wood is soft, blocky pieces; shape of log is round to oval; wood has faded to light yellow or gray; all of the log on the ground.

Decomposition 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; log fully on ground.

This protocol will result in a specific set of CWD response variables: density (number $\cdot ha^{-1}$), cumulative log length, mean large end diameter, volume of logs (based on large and small end diameter rather than taper functions by species, and log length), and cover, by species summarized by treatment unit.

QA/QC Procedures

The planned research for the fuels and CWD sampling group will likely involve a number of field personnel over time. Graduate students will be utilized as Research Assistants (RAs) and Filed Technicians (hourly). The PI will assume the responsibility of instructing all new personnel. Sally Haase has visited southern Ohio to view one site (Zaleski) and discuss the protocol for sampling the fuels (to ensure consistency with the national group). Periodic measurements will be recorded by the PI or others (blind) to confirm precision. All computer data entry will be cross-checked by an independent data analyst for completeness, accuracy, and precision.

All data will be stored in field log books, computers, and backup digital media at the laboratory of the PI. Numeric data will be entered and stored in spreadsheet form compatible with Excel. File headers will identify fields, units, experimental conditions, and other relevant information. All files will be readily convertible to ASCII files.

Wildlife

FFS response variables and protocols will be used, and per the national FFS program, a JVA will be used to collaborate with Dr. Steve Zack (Wildlife Conservation Society) that will include his direct oversight and the hiring, training, and supervision of non-Forest Service wildlife crews. The protocols to be used at Ohio Hills, as described in the sections below, follow those approved for the JFSP FFS national program with minor changes to accommodate the deciduous forest habitat (Table 5). There are four major goals of the study. First, the diversity and abundance of birds in response to the vegetation treatments will be assessed through the use of point count censuses. Second, nest productivity (number of young fledged per nest initiated and percent of nests successfully producing young) of nesting birds will be monitored in a subset of sites. Third, the functional response of foraging woodpeckers and other bark-gleaners to the treatments will be estimated. Fourth, the abundance and diversity of mammals and reptiles in response to the vegetation treatments will be estimated.

Hypotheses

A. The vegetation treatments that are a part of the FFS program entail various forms of disturbance to intact forests. The response of wildlife species to this disturbance is a key aspect of the study.

B. The null hypothesis for diversity of wildlife species (birds, mammals, reptiles and amphibians is that the treatments have no effect on species composition or abundance. Because disturbance can create new habitat it is possible that a shift in species composition occurs as a consequence of the thinning and thinning/burn treatments.

C. The null hypothesis for nest productivity is no change in number of young fledged per nest. Because the vegetation treatments involve the selective removal of trees in addition to burning the leaf litter, we predict that the abundance of some nesting species observed in the pretreatment censuses may not nest in subsequent years, e.g., ground nesting species. It is also possible that the disturbance results in an increase in nest predation by Brown-headed Cowbirds.

D. The null hypothesis for the functional response of woodpeckers and other bark gleaners is no change in foraging behavior. Alternatively, removal of trees may create additional foraging opportunities for bark probing/gleaning species.

Little data are available regarding the effects of vegetation treatments on mammals and amphibians and reptiles. The vegetation treatments may prove to be beneficial to reptiles as a consequence of the creation of more open habitats. However, small mammals may be sensitive to habitat change and a shift in species diversity may result in response to changes in forest structure.

Methods

Avian Species Diversity and Abundance

Point counts are a standardized method (Ralph and others 1993) of assessing the diversity and abundance of birds by counting individuals (detected by hearing and by sight) at fixed points. As the treatment units will have grid points at every 50m, wildlife teams will assess birds at every 200 m, with 50 m radii of detection . Depending on the shape of each treatment unit four to six points per unit will be assessed for five minutes per point. Each treatment (the four replicates of control, fire-only, fire plus thinning, and thinning-only) will be assessed six times (six replicates per treatment unit) during the two-month spring-summer breeding season. Most breeding species arrive at the Ohio Hills site in late April – early May and initiate breeding behaviors by mid May. Singing activity ceases by mid July, which makes censusing difficult. Therefore, point-counts at the Ohio Hills will begin in Early May. The main output of this method will be an assessment of the number of species (diversity) and number per species (abundance) of birds detected as a function of controls and treatments.

Nest Productivity

Nest productivity (i.e., assessment of the production of young/nest of a given species) will be assessed by standardized methods (Ralph et al., 1993). Wildlife crews will randomly assign two replicates of each treatment (including controls) to be thoroughly searched for bird nests and monitored until the fate (fledging young or failure) has been determined. The data will be analyzed in terms of overall productivity, and analyzed by categories (cavity vs. cup-nesters vs. ground nesters) and by species.

Functional Response

Evaluating the “functional” response of woodpeckers and other bark-gleaning birds (e.g., black and white warblers, chickadees, titmice, nuthatches, brown creepers) will involve observing their foraging patterns on trees in each site, emphasizing tree condition (including “risk rating”), dbh, and a measure of fire-scarring. Because woodpeckers forage on larval bark beetles and other insects infecting tree tissue, and ultimately create cavities essential for wildlife from several taxa, the response of woodpeckers to the proposed treatments will be emphasized. The wildlife team will evaluate woodpecker response by quantifying foraging excavations on bark-beetle infested trees during each year of the study and look for evidence of cavity excavation in these and other snags. Microhabitat measurements will be made near each nest (e.g., substrate measures, cover) and each woodpecker or bark-gleaner tree chosen for foraging. These data will be correlated with the plot data taken by the vegetation team so that both teams can collect data in a comparable manner. All of the foraging and microhabitat observations will be referenced to the nearest grid point.

Diversity and Abundance of Mammals and the Herpetofauna

It is generally quite costly and time intensive to effectively sample populations of small mammals and the herpetofauna. However, there are methods being developed that may provide better sampling reliability at lesser cost. The wildlife crew under the direction of the FFS program wildlife leader will establish a 6 X 6 grid, with grid points spaced 40 m – 50,m apart, on each plot with one Sherman XLK and one Tomahawk #201 at each grid point, and a pitfall trap at every other grid point. Traps will be spaced at 25m intervals. Pitfall traps will be kept dry because the objectives are to reduce the impact on the mammal and herpetofaunal population. Furthermore, because our population estimates are based on capture-mark-recapture indices, it is imperative to minimize mortality so as to enhance the recapture of marked animals.

Traps will be inspected morning and night for 10 day/night periods, unless recapture rates reach 100% at each experimental area. This inspection interval will reduce mortality. It will also ensure that traps are available in both daylight and night hours, thereby affording the greatest potential for capturing specimens of all species present. Also, the Ohio Hills site has fewer small mammal and herpetofauna species; hence all animals may be captured in a period less than 10 days. Trapping will be completed within an approximate one-month period after the juvenile mammals appear. These methods should do a reliable job of sampling the ground-dwelling small mammals and herpetofauna; however, these methods will probably not suffice for arboreal or fossorial mammals for which there are no cost-effective methods available. The Ohio Hills wildlife crew will also monitor pitfall traps during late winter and early spring to assess the diversity and abundance of amphibian species. This is necessary, because most amphibians, e.g., Salamanders, are mainly active in the cooler, wetter part of the year.

For the more abundant taxa, estimates of absolute abundance or at least relative abundance will be developed. For less abundant taxa, presence vs. absence information may be the most quantitative analysis possible. Taxa will be aggregated as appropriate to develop analyses of population differences among functional groups.

The wildlife team will interact on a regular basis the vegetation crew in order to match the status (time since infection, source of infection) of infected trees with woodpecker foraging patterns and drilling patterns. This will allow the correlation of tree mortality with onset of cavity excavation. For woodpeckers and the other bark-gleaners the wildlife team will record the tag number of the individual tree identified during foraging observations so as to later correlate bird utilization patterns with tree characteristics. Interaction with vegetation crew will also ensure that microhabitat variables associated with nest-site choice in birds and small mammal and herpetofauna trapping sites can be correlated with the overall habitat features (e.g., tree density, shrub and herbaceous cover) on a per site basis.

Table 5. Outline of wildlife measurements, timing, scale and intensity for Ohio Hills Site

Measurement	Season	Scale	Effort	Output
Bird point counts	May - July	Every 200 m	All plots six repeat visits	

Abundance and diversity

Bird nest productivity
May-August
Where found on sampled plots
Two plots each treatment (= 8 plots total)
Young/nest per nesting species

Bird “functional response”
May-August
Sampling foraging “bark gleaners”
Two plots each treatment (= 8 plots total)
Foraging response to “treated” trees

Mammal capture-recapture
June-August
Pre- and Post-Treatment years only
6X6 grid, 40 m apart, with two live traps and, at every other trap, a pitfall trap
All plots, sampled one time/yr (10 day-night periods)
Abundance and diversity

Herpetofauna pitfall trapping
Feb – March
June - August
Pre- and Post-Treatment years
Pitfall trap at every other grid point in a 6X6 grid array (above)
All plots, sampled one time/yr (10 day-night periods)
Abundance and diversity

Quality Assurance/Quality Control Procedures

This planned research will be conducted as a team effort between the USFS NE Experimental Station scientists, Ohio State University, and the Wildlife Conservation Society, in addition to Ohio University. It will require a high degree of cooperation and coordination with the Ohio State Division of Forestry and Wildlife. Personnel performing data collection functions are responsible for operational maintenance and calibration of any measuring or recording instrument, e.g., Pesola scales. Accuracy of each instrument will be maintained using manufacture’s recommended procedures for daily calibration and annual maintenance. All personnel responsible for point count censuses are supervised for one – two weeks prior to data collection to verify accuracy in species identification. Approximately 10 percent of morphological measures (tree diameters, char height, canopy cover of herbaceous species, soil bulk density, etc.) will be remeasured (blind resampling) to determine precision levels. For computer entry and data reduction, the identified personnel are responsible for verification of data entry, documentation of data completeness, accuracy, precision, and implementation of corrective action.

Data will be stored in log books, note cards, computers, and backup disks. In addition, we will archive data on CD-ROM. Numeric data will be entered and stored in spreadsheet form compatible with Excel. Data can be easily converted to other formats, such as QuattroPro. File headers will identify fields, units, experimental conditions, and other relevant information. All files will be readily convertible to ASCII files.

Utilization

Economic costs and benefits are associated with reducing fuel loads in forests, whether through wildfires, controlled burns, or mechanical methods. If mechanical methods (silvicultural cuttings) are prescribed as a method of reducing fuel loads, then the value of the wood removed might assist in offsetting the costs of the cutting practice. The information derived from the study of treatment costs and benefits will be useful to policy makers and resource managers in determining alternatives to fire in reducing fuel loads and creating forests of fire-like conditions.

Accordingly, this study will focus on the methodology and costs of treatment, and the quantity and value/ potential value of wood removed. The potential trade-offs among the costs and financial benefits associated with the use of mechanical removals, removals as the result of fire, and the combination of these two will be studied in forests of Ohio's Hill Country. This analysis will include the full cost of implementing these methods of removals, such as program administration costs incurred by agencies involved.

Two different methods of mechanical removals will be employed and studied. Two of the three sites will use the conventional chainsaw and skidder for removals, while the third site will employ the use of bulldozers and a grapple skidder. The costs, productivity rates, and subsequent benefits associated with these two systems will be studied.

METHODS

Compartment-level harvest productivity data will be collected for each function (felling, pre-bunching, skidding, etc.). Information will be collected on multiple operational compartments at each site, and will include operating hours, volume removed, skidding/forwarding distances, felling times, and turn-cycle times. Wood volume removed in one turn-cycle will be scaled to achieve the best estimates of wood volume per turn.

As part of the post-treatment vegetation sampling, the effects of burning on tree mortality and wood quality as related to salvage value will be estimated. This will be part of the costs incurred by burning as a treatment method. This will provide the information for the final comparison of removing material through mechanized methods and burning.

Pre-Harvest Operations

Boundaries between each unit in the study will be clearly marked to avoid any confusion by loggers as to which portions of the forest are to be harvested. Trees that are to be harvested in the thinning treatment and the thin-and-burn treatment will be marked with paint in order to be readily seen by loggers. Trees will be marked in accordance with the prescription to achieve the desired future condition of the forest.

Ten 50 x 20 m vegetation plots will be randomly located within each unit in a systematic approach. Pre-harvest data will be collected from these plots in the thinning and thin-and-burn treatment units. Tree data to be measured on these plots include species, dbh, total height, and merchantable height. Trees on these plots that are marked to be harvested will thus be indicated in the data, and will have additional numbering on the stump to facilitate post-harvest measurements. This data will provide the pre-harvest stand characterization as well as the valuation of trees to be cut prior to harvest.

Harvesting compartments will be delineated within each treatment unit as appropriate. The harvesting compartment is the smallest unit for which it is readily feasible to segregate harvesting production and operating time data, and is an area that is served by a single landing. Since treatment units will have multiple aspects, the change in aspect may serve in defining harvesting compartments.

Harvest Operations

Tar Hollow State Forest

Tar Hollow State Forest will be harvested using chainsaws, bulldozers and a grapple skidder. The time required to fell each tree with a chainsaw will be recorded using digital stopwatches. The time to fell a tree will begin when the sawyer approaches the tree to determine felling direction and will end as he/she approaches the next tree. This felling time will be broken into segments of time to 1) assess felling direction, 2) felling, 3) any delimbing and processing by the sawyer, and 4) moving toward the next tree.

Cabled bulldozers will be used for pre-bunching operations and some skidding. After trees are felled and processed, bulldozers with cable/chokers will be used to pre-bunch wood along the skid trail. Pre-bunching times, distances and volumes will be measured and recorded to determine productivity of this activity, and to determine the percent of production hours and scheduled hours this activity encompasses as part of the overall operation.

The skidding operation, or turn cycle, will begin its timing sequence when the skidder leaves the landing to enter the woods for a load of wood, and will end once it returns to the landing and releases the load. The timing sequence of the skidding operation will include the segments of time to travel into the woods, acquire the full load of wood, and return to the landing to release the load. The load delivered to the landing on each cycle turn will be scaled for volume.

The dates and approximate times the loggers began and finished in each compartment will be recorded. Machine operators will estimate and record daily the amount of productive hours performed over the scheduled hours, and will likewise record the times of actual machine operation..

Zaleski State Forest and Raccoon Ecological Management Area (REMA)

The harvest of the Zaleski State Forest and REMA will be performed with the use of chainsaws and cable skidders. No pre-bunching will be performed in these harvest operations. Data loggers will be mounted on both machines to record times of activity, and information will be downloaded weekly. In addition to the gross activities recorded by these Data loggers, manual recording of operation will likewise be performed. This will provide the information for scheduled and productive hours. The dates and approximate times the loggers began and finished in each compartment will be recorded.

The time required to fell each tree with a chainsaw will be recorded using digital stopwatches. The time to fell a tree will begin when the sawyer approaches the tree to determine felling direction and will end as he/she approaches the next tree. This felling time will be broken into segments of time to 1) assess felling direction, 2) felling, 3) any delimbing and processing by the sawyer, and 4) moving toward the next tree.

The skidding operation, or turn cycle, will begin its timing sequence when the skidder leaves the landing to enter the woods for a load of wood, and will end once it returns to the landing and releases the load. The timing sequence of the skidding operation will include the segments of time to travel into the woods, acquire the full load of wood, and return to the landing to release the load. The load delivered to the landing on each cycle turn will be scaled for volume.

Harvest Production

Costs to be included in the economic analysis include machine costs (converted from annual basis to hourly rates), fuel costs, labor, extraction costs [(crew size x labor cost + hourly machine rate)/hourly production], felling costs, and costs associated with delays. During logging operations, unplanned work stoppages usually prevent a system from producing at its peak efficiency. The time during which the system is actually working is usually termed “productive” or “operating” time. Utilization, a widely used measure of logging system efficiency, is defined as the ratio of productive to scheduled time.

Many kinds of delays during a logging operation can cause scheduled time to go unutilized. Two main categories of delays can be made and will be measured in this study which include: 1) chronic delays caused by minor problems that occur repeatedly during normal operations, and 2) unplanned stoppages resulting from mechanical breakdowns, scheduling problems, or personal work habits. Minor chronic delays are usually relatively short, and occur frequently enough so that time-study data can provide a reasonable estimate of their average time. When these delays are treated in this manner, operating delays become a predictable part of the turn cycle, and therefore can be included within the productive, or utilized, time for each system. These delays will be estimated by the scheduled hours minus the productive hours.

Sample times will be taken on all aspects of the harvest operation to determine the average felling time, pre-bunching time, skidder turn time, volume per pre-bunch turn, and volume per skidder turn. This will be utilized to determine the number of machine and man-hours per volume extracted.

As part of the national plan, harvest production from each compartment will be determined from scale tickets and records for all products removed. Scale tickets will indicate from which treatment compartments the material was removed. Attempts will be made to assure that full truckloads came from one compartment. In cases where that is not possible, reasonable estimates will be made on the site as to the portion of the load that came from each compartment. An estimation of amount and value of the wood removed will be determined from pre- and post harvest data collected from the ten 50 x 20 m vegetation plots in each unit.

V. Quality Assurance/Quality Control Procedures

This planned research will be conducted as a team effort between the NE Station scientists, and various universities, in addition to contracts with individuals. It will require a high degree of cooperation and coordination. Personnel performing data collection functions are responsible for operational maintenance and calibration of any measuring or recording instrument. Accuracy of each instrument will be maintained using manufacture’s recommended procedures for daily calibration and annual maintenance. Approximately 10 percent of morphological measures (tree diameters, char height, canopy cover of herbaceous species, soil bulk density, etc.) will be remeasured (blind resampling) to determine precision levels. For computer entry and data reduction, the identified personnel are responsible for verification of data entry, documentation of data completeness, accuracy, precision, and implementation of corrective action.

Data will be stored in log books, computers, and backup disks. Numeric data will be entered and stored in spreadsheet form compatible with Excel. File headers will identify fields, units, experimental conditions, and other relevant information. All files will be readily convertible to ASCII files. Complete pretreatment data currently exists for all treatment units; data resides with site disciplinary leaders. All pretreatment data in electronic format at the 50-m grid point scale will be migrated to a corporate database when templates are provided by the national FFS database manager, and maintained on the FS network. Backups and the complete study file, including documentation of methods and equipment used, training and certification of personnel, any notes from field personnel, study plan amendments, copies of manuscripts and technology transfer materials, and safety documentation will be housed in fireproof storage at Delaware.

VI. Application of Research Results

While fire may remove down woody material, it may also reduce foraging habitat for birds and numerous macro-invertebrate species. Measuring both the effects of fire and/or thinning on oak regeneration and on components of biodiversity may help to identify thresholds that would be useful for fine-tuning management to achieve more holistic objectives. Measuring belowground variables in a treatment context should help to better understand the interplay between rotting wood and the soil environment. Because decomposing wood plays an important role in nutrient cycling, measuring the effects of fire and/or thinning, as well as soil chemistry and plant growth, should help identify ecological tradeoffs inherent in the application of management activities. Finally, since the Ohio Hills project will collect both ecological and economic data on common sites under similar conditions, managers will be able to assess tradeoffs between these two broad classes of information.

The JFSP FFS network, of which the Ohio Hills Site is one of eleven sites, is in response to the perception among managers, scientists and policy makers that seasonally dry forest ecosystems nationwide are at increased risk. Each participating site will apply the same four treatments (control, burn, thin and burn, thin) replicated at least three times, measure the same set of core response variables with a common plot design and over the same relative time period. Common experimental design between sites and sampling design within sites will allow three distinct and useful types of analysis in addition to the typical non-integrated, single discipline analysis: 1) integrated, multidisciplinary analyses among disciplines at the site scale (ANOVA, Regression); 2) integrated, single disciplinary analyses among sites (ANOVA); and 3) summary comparison of multidisciplinary results among sites (descriptive statistics). Because communication among sites will be facilitated by a network structure, participating scientists will gain perspective from other sites as they carry out their own site-specific work, and will be able to analyze their data within a richer context. Managers will also benefit, especially if repeatable patterns of results are observed where fire and fire surrogate treatments are applied nationwide.

The expectation is that the Ohio Hills study will yield part of a Ph.D. dissertation on the fire ecology of hardwood forest in southeastern Ohio; part of one or more Ph.D. dissertations on below-ground processes; M.S. theses on the relationship of FFS treatments to hardwood regeneration and wildlife populations, and utilization and economics of small stems in a pulpwood market. Additional abstracts will be published at national, regional and state scientific meetings and 10 to 15 papers in peer-reviewed journals are the expected results. Periodic meetings of cooperators and agency personnel will help integrate the information into specific applied management recommendations.

Table 6. Communication deliverables, audience, and time frame.

Deliverable	Policy Makers	Collaborators	Public	Resource Mgrs.	Media	Students	Time Frame
Tours	X	X	X	X	X	X	2000, ongoing
Pamphlets	X	X	X	X	X	X	2000, 2001, 2003
Meetings		X		X			Quarterly
Popular Articles	X		X	X		X	2000, 2001, 2004
Scientific Articles		X		X		X	2002, 2005
Displays			X	X			2001, 2003, 2004
Workshops		X	X	X		X	2004
Interviews	X				X		2001, ongoing
Press Release					X		2001
Signage	X		X	X	X	X	2000, 2001, 2003

VIII. Safety and Health

NE and university personnel will be conducting much of the fieldwork under normal field conditions. All Federal personnel will be informed of and operate under approved safety procedures as detailed in FSH 6709.11–Health and Safety Code Handbook. Supervisors will ensure appropriate Job Hazard Analyses are completed before work begins. Safety and health issues for those operating under contract, cooperative agreement, or joint venture agreement are not addressed here.

IX. Environmental Analysis Considerations

This study is not being performed on Federal Land. No Federal environmental analyses are required. All analyses required by the state of Ohio for Tar Hollow and Zaleski State Forests have been conducted by the Ohio Department of Natural Resources, Division of Forestry. Mead Paper Corporation has conducted the analyses required to meet the Sustainable Forest Initiative (SFI) of the American Forest and Paper Association (AF&PA). Mead has undergone the AF&PA third-party Certification to verify its adherence to the SFI standards.

X. Personnel Assignment, Time of Completion, and Cost

The pathology, most of the vegetation, and some of the fuels data will be collected and analyzed by permanent Forest Service research personnel and temporary technicians and aids. The other scientific discipline data will be collected and analyzed by employees of the cooperating universities. Those responsible for data collection and time of completion for these tasks can be found in Table 1.

Budget items approved by the JFSP are listed in table 7.

Table 7. Site budget for the Ohio Hills Site, a site in the national FFS network

	FY00	FY01	FY02	FY03	FY04
Salaries and Benefits					
Research Associates					
Pathogens (FS GS-11 33%)	$ 13,384	$ 13,786	$ -	$ -	$ 15,064
Wildlife (OU MS)	$ 14,238	$ 14,665	$ 15,105	$ 15,558	$ 16,025
Fire (OU PhD)	$ 17,445	$ 17,968	$ -	$ -	$ 19,636
Vegetation (OU MS)	$ 14,238	$ 14,665	$ -	$ -	$ 16,025
Utilization (OSU MS)	$ 8,000	$ 2,000	$ -	$ -	$ -
Research Assistants					
Soils (OSU Laboratory Assistant)	$ 26,400	$ 27,192	$ 11,330	$ -	$ 30,900
Student Labor (OSU Soils)	$ 4,500	$ 4,635	$ 2,500	$ 2,400	$ 5,000
Wildlife Field Crew Leader (OU)	$ 3,600	$ 3,600	$ -	$ -	$ -
Wildlife field crew (OU)	$ 14,286	$ 14,286	$ 7,519	$ 7,519	$ 7,519
Fire Behavior Crew (OU)	$ 5,500	$ 5,500	$ -	$ -	$ -
USFS GS-4 (Veg. Maint.)	$ 20,733	$ 21,355	$ 21,996	$ 22,656	$ 23,335
Clerk/Typist (GS-3)	$ 18,470	$ 19,024	$ 15,676	$ 16,146	$ 16,631
Fringe	$ 30,339	$ 30,416	$ 16,806	$ 15,862	$ 29,572
Total Salaries and Benefits	**$ 191,133**	**$189,092**	**$ 90,932**	**$ 80,141**	**$179,707**
Travel					
National Meetings	$ 7,000	$ 8,000	$ 9,000	$ 7,500	$ 8,000
Field Work	$ 13,000	$ 13,000	$ 5,000	$ 5,000	$ 8,000
Total Travel	**$ 20,000**	**$ 21,000**	**$ 14,000**	**$ 12,500**	**$ 16,000**
Nonexpendable Equipment					
Plot Setup and Maintenance	$ 1,625	$ 250	$ 250	$ 250	$ 250

Traps and Scales	$ 5,000	$ -	$ -	$ -	$ -
Computers and Peripherals	$ 10,000	$ 1,500	$ 500	$ 500	$ 500
Pathology tools and equipment	$ 7,000	$ 3,500	$ -	$ -	$ 3,500
Microplate Reader	$ 7,185	$ -	$ -	$ -	$ -
Pipetters (2)	$ 1,260	$ -	$ -	$ -	$ -
All Terrain Vehicle	$ 7,000	$ -	$ -	$ -	$ -
Total Nonexpendable Equipment	**$ 39,070**	**$ 5,250**	**$ 750**	**$ 750**	**$ 4,250**
Contracts					
Aerial Photography	$ 5,000	$ -	$ -	$ -	$ 5,000
Total Contracts	**$ 5,000**	**$ -**	**$ -**	**$ -**	**$ 5,000**
Supplies					
Plot setup and maintenance	$ 1,000	$ 250	$ 250	$ 250	$ 250
Soils	$ 5,000	$ 5,000	$ 1,000	$ 1,000	$ 6,000
Wildlife	$ 2,000	$ 2,000	$ 2,000	$ 2,000	$ 2,000
Fire Behavior	$ 1,000	$ 1,000	$ -	$ -	$ -
Total Supplies	**$ 9,000**	**$ 8,250**	**$ 3,250**	**$ 3,250**	**$ 8,250**
Total Direct Costs	**$ 264,203**	**$223,592**	**$108,932**	**$ 96,641**	**$213,207**
Indirect Costs	$ 47,375	$ 39,496	$ 17,789	$ 15,090	$ 37,010
Annual Funding Required	**$ 311,578**	**$263,088**	**$126,720**	**$ 111,731**	**$250,217**
Total Funding Required	**$ 1,063,334**				

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