The Role of Silvicultural Thinning in Eastern Forests Threatened by Hemlock Woolly Adelgid (*Adelges tsugae*)

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ABSTRACT

In order to increase hemlock survivability in stands threatened by hemlock woolly adelgid (HWA), a new study is developing silvicultural thinning guidelines to reduce stand densities, reallocate resources, and increase hemlock vigor across a range of stand types and structures before HWA invasion. The 7 study areas are all geographically similar in that they regularly experience winter temperatures that can be lethal to hemlock woolly adelgid. The combined effects of climate and silvicultural treatment may serve to moderate adelgid populations and increase hemlock survival. Four Pennsylvania stands received thinnings in 2006 to reduce relative stand density by 30-40%. Half of each stand was not harvested and serve as controls. In New England, four additional sites will be thinned in 2007-08. Pre- and post-harvest sampling includes measurements of stand density and structure, residual "crop" tree stems and crowns; understory vegetation; soil moisture, temperature and nutrients; foliar nutrients; and insect populations.

Keywords: hemlock woolly adelgid, silvicultural thinning, stocking, foliar nutrients

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INTRODUCTION

The hemlock woolly adelgid, (HWA, ***Adelges tsugae*** Annand) is a major threat to the health and sustainability of Eastern North American hemlock species – eastern hemlock (***Tsuga canadensis*** (L.) Carr.) and Carolina hemlock (***Tsuga caroliniana Engelm***.) (Knauer et al. 2002). This introduced insect is currently found in 17 states, covers approximately 50% of eastern hemlock's range (http://www.na.fs.fed.us/fhp/hwa/maps/hwa_2006.pdf), and is causing tree decline and wide-ranging mortality effects. Hemlock mortality associated with HWA establishment can range from almost none to 95% (Bair 2002, Mayer et al. 2002, Orwig and Foster 1998). Mortality can occur quickly and uniformly throughout a stand, especially in the presence of other stressors, or can occur slowly and in patches for more than a decade. The resulting effects on stand dynamics may cause changes in species dominance, age and canopy structures, (Orwig and Foster 1998, Stadler et al. 2006) and hence management direction.

HWA is rapidly spreading to new areas at a rate of 15.6 km/year south of Pennsylvania and 8.13 km/year (or less) in the northern portion of hemlock's range (Evans and Gregoire 2007). Colder winter temperatures are believed to slow spread rates (Evans and Gregoire 2007, Parker et al. 1999). HWA attacks all sizes and ages of hemlock from seedlings to mature canopy trees. Adelgid feeding depletes hemlock's stored nutrient reserves causing a reduction in new shoot production in infested parts of the crown, followed by needle drop, branch tip dieback, foliage thinning, lower branch dieback and mortality in 2 to15+ years (McClure 2001, Mayer et. al 2002, Orwig 2002). Biological and chemical methods to control the pest are costly and impractical for large forest tracts.

The wide range in the rate and extent of eastern hemlock decline and mortality suggest that tree and site variables influence the response of hemlock to HWA infestation. A new study is being implemented to determine if stand structure manipulations can be used ahead of the leading edge of HWA invasion to increase individual host tree and stand resistance. Specifically, silvicultural thinning treatments are being used to remove low vigor trees, which would reallocate site resources to enhance the health of the remaining hemlocks. However, nothing is known about whether such treatments are effective in HWA control. Because thinning also alters forest climate, and soil and foliar nutrient cycles (Van Cleve and Zasada 1979), the attractiveness of thinned stands to HWA feeding must also be evaluated. Therefore, research is needed to determine whether thinning mixed hemlock-hardwood stands to increase the vigor of hemlock trees ahead of the leading edge of HWA will also increase hemlock survivability when HWA attacks a stand. The project involves the collaborative efforts of many individuals from federal and state agencies located in the mid-Atlantic and New England states. Working across organizations and ownerships will develop linkages necessary to translate the research findings quickly and directly to natural resource managers for application.

The study has two objectives. The first is to determine whether thinning mixed hemlock-hardwood stands to increase the vigor of hemlock trees prior to the arrival of HWA will increase the survivability of hemlock when HWA attacks a stand. Scientific and empirical evidence indicates that while healthy hemlocks are not less susceptible to attack, they do have a better chance of surviving longer than stressed trees (e.g., crowded conditions). Increased survivorship may improve hemlock's chances for recovery (Orwig and Foster 1998), especially if HWA populations crash and/or effective biological controls are developed. To monitor the effects of thinning, it is critical in this study that the approximate time of arrival and subsequent spread of HWA in these stands be carefully monitored. The results from the study will provide management options to forest landowners and land managers faced with pending HWA invasion and potentially prevent pre-emptive harvesting of hemlock, which can contribute to future regeneration failures of this species (Brooks 2004).

A second objective is to monitor ecological changes in forest structure as an HWA infestation progresses in thinned and unthinned stands. Treatments are established in a variety of stand structures located on a range of site conditions in the northern portion of hemlock's range. A number of tree health variables (e.g. mortality, foliage density, foliar nutrients, crown transparency, percent dieback, direct HWA counts, and amount of new crown and stem growth) are used to measure the effects of thinning, and subsequent HWA infestation, on hemlock growth and survival (Colbert et al. 2002, Kimple and Schuster 2002, Scudder et al. 2002). Because both thinning and insect infestation can cause increases in soil N mineralization and nitrification rates, in some of the study areas, soil and foliar sampling are also included.

BACKGROUND

Use of Silviculture in Invasive Species Management

Loss of a tree species due to an introduced pest can initiate ecological change and have potential economic effects (Liebhold et al. 1995). The appropriate silvicultural treatment for managing introduced forest pests requires an understanding of the ecological interactions of both the pest and the host species. Integration of silvicultural techniques at a variety of spatial and temporal scales may be necessary to prevent or mitigate the effects of a pest invasion. Because introduced pests have no natural enemies in native forests, traditional silvicultural approaches designed for managing native pests, such as sanitation or salvage operations (Smith et al. 1997) may need to be modified (Waring and O'Hara 2005).

Hemlock's ecological role in eastern forests far outweighs its economic importance. Hemlock's wood characteristics limit its commercial use to relatively low-grade products (Howard et al. 2000) for which market substitutions are easily made. Conversely, hemlocks occupy an extraordinarily important ecological niche in both pure stands and growing in mixture with hardwoods. The species are very tolerant of shade and typically are found in understory positions as well as in sub-dominant overstory canopy positions. Dense hemlock understories utilize growing space that would be lost to less shade-tolerant species (Kelty 1989), provide winter cover and vertical structure for many wildlife species (DeGraaf et. al 1992), and maintain aquatic habitat integrity by shading streams (Evans 2002). Hemlocks grow slowly even when young and at high densities can survive in supressed conditions for hundreds of years (Godman and Lancaster 1990). Self-thinning is slow and canopy disturbance is typically required for accelerated growth to occur.

The extent to which the presence of other insects, site conditions, and stand structure affect hemlock's susceptibility to HWA or vice-versa is still unclear. Hemlocks growing in areas with adequate, consistent moisture are generally less vulnerable to attack and can survive an HWA infestation better than trees growing on droughty or waterlogged sites (Mayer et al. 2002, Orwig 2002, Sivaramakrishnan and Berlyn 2000, Ward et al. 2004). HWA impacts to stem and branch growth typically progress upward from the lower crown, and reduced growth and possible mortality occur depending on infestation intensity and duration. Hemlocks in dominant and codominant overstory crown class positions had lower mortality during moderate infestations than overtopped and intermediate class trees (Orwig and Foster 1998). However, new evidence suggests that live-crown ratio may have a stronger relationship with vulnerability regardless of crown class (Rentch 2007).

HWA invasions typically follow three phases: arrival, establishment and spread (National Research Council 2002). Combined with local quarantines, preventive silvicultural techniques can be used along the leading edge of a HWA outbreak prior to arrival. Seasonal alterations in management activities (e.g. road closures, harvesting) near HWA infested areas can also be preventive (Waring and O'Hara 2005). Curbing management activities during HWA crawler emergence in both early spring and mid-summer may help curtail spread.

Reduction in stand density through thinning and removal of the most vulnerable individuals of targeted host species can be used alone or in combination with eradication tools, to reduce potential infestation targets and minimize mortality. For example, the goal of thinnings used to lower the density of gypsy moth-preferred host species is to select crop trees with the most vigorous crowns because healthier trees can survive years of defoliation (Gottschalk 1993). The best results from this type of density manipulation occur when the treatments are applied before arrival of the pest.

Specific chemical characteristics of the foliage may affect a tree's resistance to HWA or may act as a physiological defense strategy (Clancy et. al 2004). Healthy hemlock forests typically have slow decomposition and N-cycling rates because of their low foliar N content and cool microclimate. Trees infested with HWA were found to have significantly higher needle concentrations of N, Ca, K, Mn, Al, lignin and cellulose compared to those not infested (Pontius et al. 2002); although, total soil nutrient content did not change in infested stands. HWA feeding and needle mortality effects nutrient cycling in the canopy, the chemical composition of the litter, and hence nutrient availability in biogeochemical cycles (Stadler et al. 2006). In HWA-infested forests, nitrogen mineralization and nitrification rates are higher than uninfested forests (Jenkins et al., 1999, Yorks et al. 2000). Yet, there is a decline in nitrogen fluxes over time as infestation increases and needle biomass decreases (Stadler et al. 2006).

Thinning also effects biogeochemical cycles because of increases in light, soil temperature, soil moisture, and litter and root system decomposition, at least until canopy closure (Van Cleve and Zasada 1976). Thinning hemlock stands will probably cause temporary increases in soil nitrification rates, which may or may not cause increases in foliar N and other elements. Depending on individual site conditions for a given stand, microbial soil populations can increase enough to tie up nitrogen so that foliar amounts remain unchanged (Van Cleve and Zasada 1976).

After arrival, the next invasion phase occurs when the pest begins the process of establishing a permanent population. Early in the establishment phase when pest populations are typically low, biological and chemical eradication tools can be successful for removal of all or most individuals, especially if treatments are repeated. There are several insecticides used for controlling HWA (McClure 1991b) but these are only effective as individual tree applications, restricting their use in treating entire stands.

Once an established population begins to rapidly increase, silvicultural efforts should focus on containment of the pest. HWA has been spreading through the Eastern United States for over 50 years (Cheah et al. 2004). Spread rates were initially slow but have increased substantially in the last decade (Ward et. al 2004). In the spread phase, silvicultural efforts target reducing host damage/mortality and slowing the spread.

Detection and assessment of HWA

Understanding HWA's complex reproduction cycle is important for monitoring population spread and for planning silvicultural activities. HWA produces abundant progeny in two parthenogenetic (all-female) wingless generations per year. The winter generation develops over 9-10 months (early summer to mid-spring of the following year) and the spring generation occurs from spring to early summer of the same year. These generations overlap in middle to late spring and life cycle timing is influenced by local climate. The winter generation lays up to 300 eggs per female in late winter/very early spring (McClure et al. 2001). The eggs hatch in April and May and mobile brownish-red nymphs ("crawlers") crawl along the branches but can only be dispersed between trees by wind, animals and humans. Crawlers settle on twigs and insert their stylets into the base of hemlock needles and obtain nutrients from xylem ray tissue (Young et al. 1995). They remain at the same feeding site for 4 nymphal stages and develop into adults in early June. These spring generation adults lay eggs between mid-June to July, but the number of eggs produced is only 20-75 per adult (McClure 1989). Eggs hatch in early July, enter a summer dormancy period and begin feeding around October. The prolonged winter feeding of this generation allows it to tap into a tree's stored food reserves in the absence of any potential predators.

Several studies examined the spatial distribution and dispersion patterns of HWA throughout the forest (McClure 1990, Gray et al. 1998, Kimple and Schuster 2002). Other studies on egg, crawler and adult distributions (McClure 1990, 1991a, Evans 2004) suggest that HWA is evenly distributed throughout the vertical layers of forest and tree canopies. More recently, however, entire stem and branch dissections reveal that in trees with high HWA populations a larger percentage of nymphs are found in the lower crown while in trees with low HWA populations a larger percentage of nymphs are found in the upper crown (Evans and Gregoire 2007). These findings suggest that early detection of HWA invasion would be more difficult because the population would at first be more numerous in the inaccessible upper crown. Costa (2005) developed a sampling plan for the detection of HWA but it is based on sampling only lower branches within reach. A modified version of his sampling system, as well as visual observation with binoculars will serve as the foundation for the detection surveys in this study. Impact survey assessments similar to those used by Colbert et al. (2002) will be used to measure the effects of HWA on hemlock tree health variables.

Management Guidelines for Hemlock-Hardwood Stands Threatened by HWA

Current management guidelines target stands with an identified HWA infestation and anticipated hemlock decline and mortality within several years. Management options include harvesting stands before notable decline, salvage harvesting, felling trees without removal, protecting individual trees using biological controls or insecticides, and taking no action (Ward et. al 2004). Stands are prioritized for type and intensity of management activities based on economic, ecological, esthetic criteria and site characteristics. Regardless of management objective, stands are selected for treatment with the goal of maintaining their health and vigor until effective biological controls are developed.

There are few thinning studies in hemlock-hardwood stands that focus on reducing stand density to favor hemlock growth. Hemlock height and diameter growth after crown release is related to how dense the preharvest stand was and a tree's canopy status (overstory vs. understory) (Merrill and Hawley 1924, Marshall 1927). Trees growing in dense stands showed 60% greater growth after thinning (from above and below) than stands that were understocked. Stands with higher hemlock stocking exclude more rapidly growing shade intolerant competitors and growth is concentrated on the main stem instead of branches (Tubbs 1977). Hemlocks previously growing in suppressed canopy positions tend to have better stem form and faster growth after release than open-grown associates of similar size. Age appears to be a minor factor in tree growth response; older trees typically grow better than younger ones unless a tree has been suppressed for so many decades (>60 years) that it has lost too much crown area to increase growth (Marshall 1927). Generally, hemlock can be thought of as a species that shows a growth response to environmental change based on its size (e.g. smaller trees grow faster than larger trees) and not its age. Evidence from thinned hemlock stands indicates that hemlock can continue favorable volume increases through at least age 200 (Ward and Smith 2000). Current management guidelines recommend that thinning operations should remove at least 6 to 7 m^2/ha of basal area; however, if stands are very dense (> 46 m^2/ha), basal area removal should not exceed more than 1/3 of the total in any given operation (Lancaster 1985).

In this study, thinnings are designed to reduce stand densities in fully-stocked and overstocked hemlock-hardwood stands and hemlock-hardwood-white pine (*Pinus strobus* L.) stands. When a stand is at full-stocking it contains the maximum sustainable amount of foliage given fixed site resources. Fixed site resources are those resources that cannot be manipulated silviculturally (Vose and Allen 1988). Thinnings reallocate fixed resources among fewer stems increasing the amount of light, water and nutrients per tree. Foliar quantity is affected because of modifications to the branch size – foliage weight relationship and the number and (or) size of branches within the crown (Gillespie et al. 1994). Healthier hemlocks can tolerate high densities of HWA better than can trees of low vigor (McClure 1995, Sivaramakrishnan and Berlyn 2000) and hence may survive or persist longer during an infestation. However, because thinning affects foliar nutrient content, measuring the changes in foliar nutrients in thinned and unthinned stands prior to and during HWA infestation, may indicate whether silvicultural manipulations make hemlocks more or less attractive to HWA attack.

In this study, the silvicultural approach to HWA management is modeled after the gypsy moth management guidelines developed by Gottschalk (1993) from research conducted since the early 1980s. Currently, all standard silvicultural thinning guidelines for hemlock-hardwood stands are based on data from stands in New England and the Lake States (Lancaster 1985, Tubbs 1977), and none of them addresses mitigating the impacts of HWA. Because the study sites are located in areas either on the leading edge of the invasion or up to 10 years away from invasion, pre-arrival stand conditions can be measured, silvicultural treatments applied, and ecosystem responses after arrival and establishment can be monitored.

METHODS

Site Selection

Study sites, on federal and nonfederal land, are being used in the study. Selection criteria include stand size, soil/site limitations to harvest, and stand structure (density, species composition, hemlock component). Stands need to be at least 24 ha and have a minimum of 7 m2/ha of hemlock basal area distributed uniformly throughout the stand. As of May 2007, four stands received treatments on the Allegheny National Forest in northwestern Pennsylvania. An additional Pennsylvania stand, managed by the Pennsylvania Game Commission, is currently being marked for thinning. All those areas were initially overstocked with total basal areas averaging around 46 m2/ha. Three study areas in New England will be thinned in summer/fall 2007. Two stands are on Massachusetts state forest land and the other stand is located at the U.S. Department of the Air Force, New Boston Air Force Station in New Hampshire.

Treatment

Prior to timber marking, six, 4-ha treatment blocks are established in each stand. Three of the treatment blocks are then randomly selected to be marked for a thinning to reduce relative stand density 30-40 percent. Because stand structures are typically spatially variable throughout the treatment areas, a combination of low and crown thinning (Smith et al. 1997) is sometimes used to remove hardwood trees overtopping hemlocks with good stem form and live crown ratios > 30%, and to reduce density in hemlock clumps. Hemlocks with <30% live crowns are less likely to respond to the treatment (Smith et al. 1997). Otherwise the treatment is primarily a crown thinning to reduce density among competing hemlocks. Both commercial and noncommercial harvests are sometimes necessary. The other three treatment blocks in each area are not thinned and serve as reference stands for sampling vegetation dynamics pre- and post-HWA invasion.

Trees are marked for thinning according to guidelines developed specific to each stand's characteristics based on recent inventory data summaries. After marking, ten, 0.04 ha circular vegetation sample plots are located in each treatment block according to a systematic random procedure wherein each block is roughly divided into ten, 0.4 ha sections and one sample plot randomly located within each section. In the blocks designated for thinning, a residual hemlock tree that was targeted for canopy release (e.g. has 3-4 surrounding stems marked for removal), serves as the plot center. This center tree is referred to as the "subject" tree. Similar selection criteria are used to identify 10 hemlocks to serve as subject trees in the untreated blocks. In addition to the subject trees, each spring 120 randomly selected hemlock "HWA monitoring" trees at each site (20 trees/block) will be examined for presence of HWA according to a procedure described by Costa (2005) as modified by Turcotte (described in Fajvan et al. 2005).

Vegetation Sampling

Plot-level vegetation measurements of overstory and understory are conducted prior to thinning and repeated the first growing season after thinning (Fajvan et al. 2005). Plots are revisited at 1, 3, 5, 7 and 9 years post harvest to re-measure the vegetation. Future sampling will be determined by timing of HWA invasion.

Measurements collected on the subject trees include: stem diameter, total height and height to base of live crown, and crown width. Crown health variables (foliage density, transparency, percent dieback) and branch tip assessments of new growth, are measured according to criteria outlined in Colbert et al (2002). On the Pennsylvania sites, soil and foliar sampling for nutrient elemental content were conducted prior to harvest and continue annually for 5 years starting the first growing season after harvest (Piatek 2006).

DISCUSSION

Because the timing, extent, and duration of HWA invasion will differ for individual study areas, each 60 + acre stand is considered an experimental unit, with 3 replicated treatment blocks each of thinned and control. Valuable information about the effects of thinning on hemlock growth, vigor, and vulnerability to HWA will be gained by monitoring the subject trees. The value of having pre-treatment and pre-HWA vegetation sampling plots will also serve to monitor changes in vegetation structure cause by HWA-induced mortality. In addition, in stands with foliar and soil elemental chemistry monitoring, data will be collected on the effects of thinning on biogeochemical cycles in hemlock-hardwood mixtures. The relationship of foliar nutrients and hemlock's attractiveness and palatability to HWA can be determined as well as the interaction of thinning and HWA infestation on elemental chemistry.

This new study faces many challenges in its implementation and subsequent monitoring. Study areas are geographically distant requiring the coordination of different field personnel to sample vegetation and monitor HWA at each location. HWA is difficult to detect during early stand invasion because initial infestations are typically in upper crown locations, so sites need to be carefully monitored.

At the northern range of HWA spread, cold winters are believed to cause slower spread rates and help explain the longer survival of infested hemlocks (Paradis et al. 2007). The study areas are all located in this northern spread range and it is hoped that the combination of silvicultural thinning to improve hemlock vigor, combined with colder temperatures, will increase survival rates. Entomologists believe that a complex of introduced predatory insects and diseases will be needed to maintain HWA below lethal levels (Ward 2004). Forest managers in the hemlock region need to test various treatments in order to maintain a hemlock component in stands while biological controls are tested and released in the field. Silvicultural thinning is one technique that can be tested in an attempt to avoid the loss of an ecologically important tree species found across most of the eastern United States.

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Hayes Creek Fuel Reduction Project: A Success Story

Kim M. Johnson

ABSTRACT

The Hayes Creek fuel reduction project was small in terms of the number of acres treated but very complex. This complexity included figuring out how to go about meeting a variety of multiple resource objectives given the values associated with a unique area. Doing fuel reduction treatments would reduce the risk of loosing the vegetation on site in the event of a wildfire however there was still a need to provide habitat for big game animals and goshawks, rejuvenate the aspen stands, and protect historic apple trees. This paper describes our project from planning through implementation and the lessons we learned along the way.

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INTRODUCTION

There are many challenges facing land managers when applying fuel reduction treatments. These challenges range from public support of fuel reduction treatments to our own internal agency planning and implementation challenges. Can proposed treatments meet multiple objectives? Are there issues with minimal to no resolution options that would make the project a "no go"? Will private land owners be supportive to treatments done on national forest land adjacent to their property? Will there be resistance from groups that traditionally litigate projects? Does the agency have the right tools in the tool bag to get the work done on the ground? Will the project pay for itself? Will the prospective contractors be receptive to a non-traditional contract? Then there are always the unknown questions and issues that arise when you least expect them. These are just some of the challenges land managers face on a day to day basis. The goal of this paper is to tell the tale of a complex fuel reduction project located within the wildland urban interface (WUI) on the Bitterroot National Forest.

PROJECT OBJECTIVES

The main objective of the Hayes Creek fuels reduction project was to "…reduce the potential for uncharacteristically intense, large-scale wildfire in the wildland urban interface by reducing the fuel loadings, creating fuel breaks, and diversifying stand structure" (USDA Forest Service, 2003). The treatments were intended to open up the overstory tree canopy through thinning and remove most of the ladder fuels from the understory. Prescribed fire would follow thinning.

While vegetation management to reduce the fire risk and change fire behavior was the primary objective, there were also other vegetation benefits that would result from proposed treatments. Thinning would reduce stocking levels and promote ponderosa pine leaving the residual vegetation in a healthier condition and lessen the risk of losing this vegetation to insects and diseases. Aspen vegetation needed rejuvenation and thinning and prescribed fire would act as the disturbance process for rejuvenation. Historic apple trees were a major component of the understory and while no formal protection was required, we wanted to retain as many of these trees on site from the historic and scenic perspective and because it was the right thing to do.

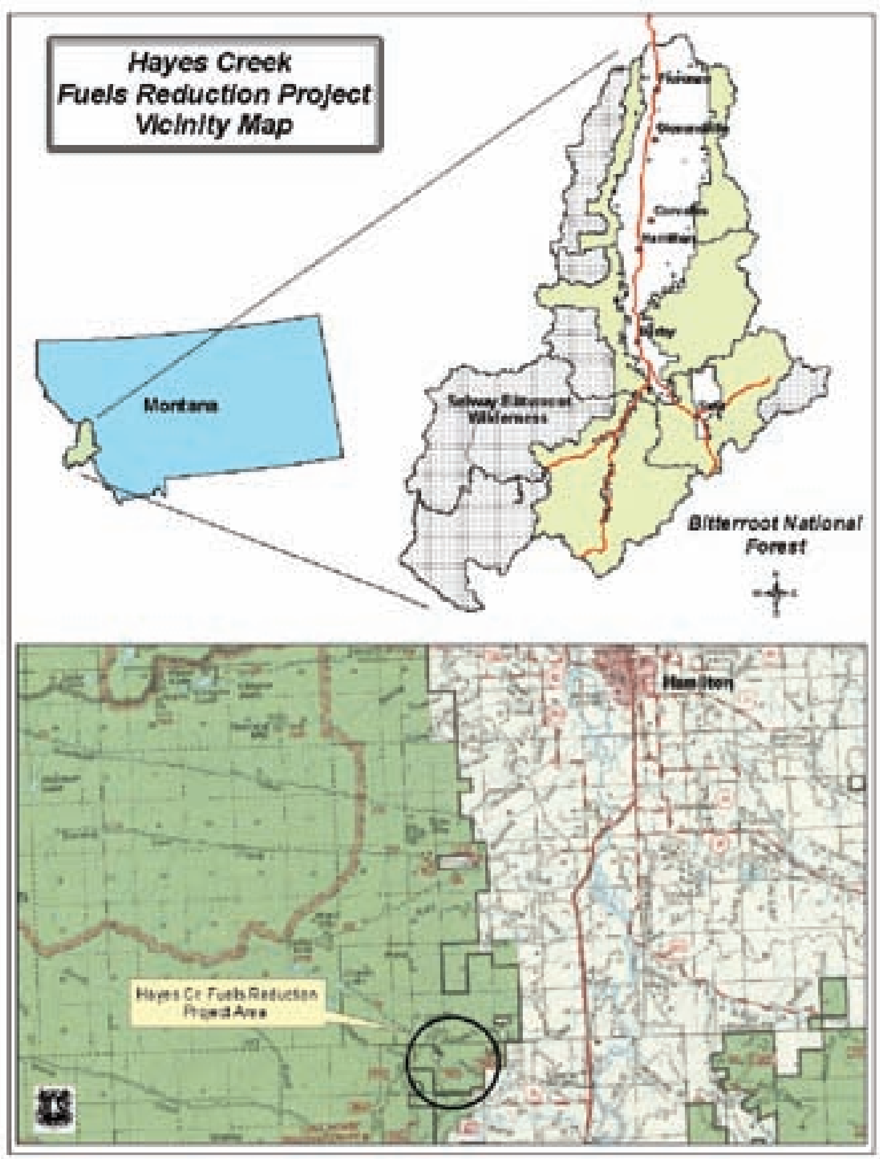

Figure 1— Hayes Creek fuel reduction project, vicinity map.

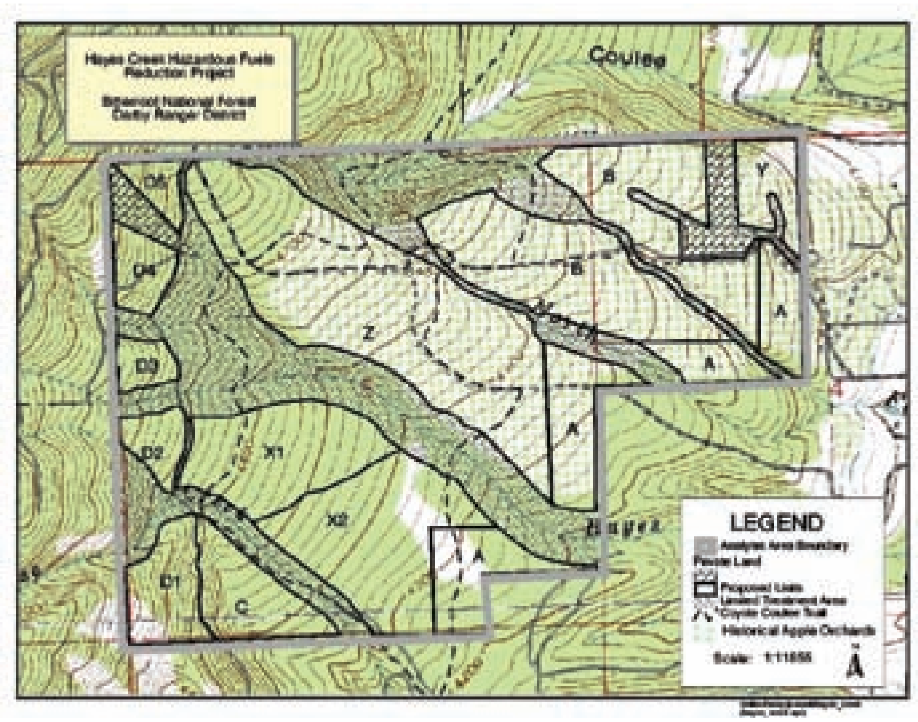

Figure 2— Hayes Creek fuel reduction project, treatment unit map.

Wildlife habitat would benefit from treatments by opening up the canopy and increasing the browse component of the understory. This worked towards meeting Forest Plan standards and guidelines of optimizing big game winter range habitat. Goshawk habitat will also be enhanced by proposed treatments. Treatments will set up the trajectory for future flammulated owl habitat.

The project was developed with coordination between wildlife, fisheries, timber sale, hydrology, soil, silviculture and heritage program resource specialists. The integrated approach ensured that the project design and prescriptions for fuel reduction treatment incorporated the appropriate forest plan standards and guidelines and met project objectives. Mitigations were developed to address other issues and concerns.

BACKGROUND

Project Area Setting

The Hayes Creek Hazardous Fuel Reduction project area is located adjacent to private land in the vicinity of Moose and Hayes Creeks and Coyote Coulee on the Darby Ranger District, Bitterroot National Forest (refer to figure 1—vicinity map). Terrain is relatively flat and rolling with drainages running west to east. Elevation ranges between 4200 to 4800 feet. The project area is approximately 680 acres in size with treatment proposed on about 440 acres (refer to figure 2—treatment unit map). The letters on the project map designate individual treatment areas.

Only one drivable road exists in the project area. This road runs within the western portion of the area (refer to figure 2), at higher elevations along the east edge of treatment units D-1 through D-5. Figure 2 shows roads through the middle of the project in treatment unit Z and B however most of these roads are actually designated as ATV trails and not drivable with cars or trucks.

The forest plan management area designation for a majority of the area is big game winter range. Standards and guidelines specify to optimize elk winter range habitat using timber and other vegetation management practices. The higher elevations of the project area are designated as visually sensitive foreground and middle ground. Standards and guidelines for this visually sensitive area are to maintain partial retention visual quality objectives and manage timber (USDA Forest Service, 1987).

PROJECT AREA HISTORY

Human Use

The project area land was acquired by the Forest in 1979. Since acquisition, minimal treatments on the land have occurred.

Historic Logging Practices

In the mid 1800s subsistence logging mainly occurred by individual land owners as the land was cleared for farming and building cabins. Subsistence logging transitioned into full blown extensive timber harvesting as settlement of the valley increased. This large scale logging effort occurred in the late 1800s to early 1900s in the Hayes Creek area by the Anaconda Copper Mining Company. The company bought up land from individual land owners and basically logged the land clean. The timber was used for railroad ties and to fuel the company copper mill in Butte, Montana. All trees over six inches in diameter were removed and the logging slash left on the ground. Logging of the time was done by horses. Logs were dragged to creeks and floated down stream during high water or dragged to the railroad track for haul to the mill.

Apple Orchards

After the large scale logging was complete in the early 1900s, apple orchards were planted on the land where ponderosa pine trees once dominated. The land was then sold to land speculators back east and these "new" land owners would hire someone to manage the orchards for them. The apple boom only lasted until about the mid 1920s. Remnants of these orchards exist on the landscape today within and outside of the project area.

Recreation Use

This area receives a high amount of recreation use. The first loop of the Coyote Coulee recreation trail system is located within the project area boundary. The low elevation of the trail system allows the trail to be enjoyed year round by horseback riders, endurance riders, cross country skiers, mountain bikers and people walking their dogs. The trail system and trailhead were greatly improved when the forest entered into a partnership with a local stake holder group.

Wildlife Use

Habitat exists for several big game species. Moose (*Alces alces*) are normally seen in riparian areas and elk (*Cervus canadensis*) can be found throughout the project area. An active goshawk nest is located just outside the project area adjacent to the recreation trail. During nesting season the bird does shown aggressive behavior to the recreating public.

CURRENT CONDITION

Vegetation

Native

Forested vegetation has slowly recovered since logging occurred in the early 1900s. Vegetation today is composed of predominantly ponderosa pine (*Pinus ponderosa* Dougl.) with Douglas-fir (*Pseudotsuga menziesii* (Mirabel) Franco) in varying amounts. As elevation increases, the land supports more of an even mixture of these two tree species. Riparian areas are composed of a variety of tree species including grand fir (*Abies grandis* (Dougl.) Lindl.), Engelmann spruce (*Picea engelmannii* Parry), quaking aspen (*Populus tremuloides* Michx.), black cottonwood (*Populas trichocarpa* T. & G.), as well as ponderosa pine and Douglas-fir.

Tree vegetation ranges in size from seedlings and saplings up to about 20 inches in diameter, with a few larger trees present in more moist areas. The majority of the conifer trees are three to 15 inches in diameter, at the most 70 feet tall and no more than 70 to 80 years old. Multiple canopy layers exist and trees are clumpy and densely stocked in appearance. Overall, tree form and crowns are good with very minor damage or forks.

Aspen

Aspen vegetation is found mainly within or immediately adjacent to riparian areas. A majority of the trees are older, small in height, and have small crown ratios. Some regeneration is occurring. Dead aspen trees are starting to fall. The overall aspen condition could be categorized as bordering on decadence in the majority of the project area.

Apple Trees

Remnants of the old apple orchards remain as an unusual but interesting component of the understory vegetation. The apple orchards are found within the project area on the north side of Hayes creek. Approximately one-third of the apple trees remain alive today and most still produce apples. The trees are very branchy and bushy (not pruned, as compared to managed apple orchards) and no more than twelve feet in height.

Fire Risk

Historic fire regimes for the project area in general would be classified as frequent, low intensity fires of low to mixed severity, typical of low elevation ponderosa pine/dry Douglas-fir sites. Fuels mainly consist of ladder fuels in the form of small size, densely stocked trees. These ladder fuels are found throughout the entire project area, situated under the crowns of the larger ponderosa pine trees as well as in dense pockets in-between the more dominant trees. Ladder fuels are also heavy in the riparian areas where a variety of conifer tree species are becoming established under the aspen. Ground fuels within the riparian area are beginning to be created as aspen trees die and fall.

Insects and Diseases

Pine engraver beetles (Ips Spp.) are present at endemic levels and have the potential to become a larger problem. Minor amounts of Armillaria root disease (*Armillaria ostoyae* (Romagnesi) Herink) are present and sparsely scattered in the higher elevations of the project area. Large size snags are basically non-existent and only a minor amount of smaller size snags are present and usually result from Ips beetle attacks or root disease.

WHY HERE WHY NOW

This project was initiated in the summer of 2003 for a variety of reasons. Fuel reduction had become a high priority for management on federal lands, especially within the wildland urban interface. The project area landscape had not experienced any commercial vegetative activity for nearly 100 years. Fuel reduction treatments had been implemented very recently on national forest land surrounding Hayes Creek. Some adjacent land owners had or were in the process of treating their land to reduce fuels and provide more protection for their homes. Treatments in Hayes Creek would nicely tie into these completed treatments. Ravalli County had completed a county wide community fire protection plan which identified the Hayes creek area as a high priority for treatment. The Healthy Forests Initiative (HFI) provided the agency additional tools that would expedite fuel reduction projects.

Healthy Forests Initiative

The Healthy Forests Initiative was proposed by President Bush in August 2002 and agencies were directed to develop administrative and legislative tools to improve regulatory processes. These tools were intended to ensure more timely decisions, greater efficiency, and better results in reducing the risk to forest and rangeland ecosystems from catastrophic wildland fires (USDA Forest Service, USDI Bureau of Land Management, 2004).

Expanded Stewardship Contracting Authority

One key component of HFI was the legislation enacted by Congress in December 2002 which expanded the stewardship contracting authority. The expanded authority allowed the Forest Service and the Bureau of Land Management to enter into long term contracts, up to 10 years in length. The contractor would keep wood products in exchange for service work of thinning trees, brush disposal and removal of dead material. Achievement of desired results on the ground would improve forest and rangeland health and provide benefits to communities (USDA Forest Service, USDI Bureau of Land Management, 2004).

Categorical Exclusion 10

Another key component was the development of two new categorical exclusions (CE) that were adopted by the Forest Service and Bureau of Land Management in June 2003. This project fit the requirements of category 10 which allowed for up to 4500 acres of prescribed fire and up to 1000 acres of mechanical activities. Mechanical activities could include crushing, piling, thinning, pruning, cutting, shipping, mulching and mowing. This categorical exclusion allowed for the sale of treated vegetative material as long as fuel reduction was the primary objective. Other criteria to meet when utilizing this CE included:

- No new roads would be built.
- There would be no sale of vegetative material that did not have hazardous fuel reduction as its primary purpose.
- No pesticides or herbicides would be used.
- Activities proposed would only be allowed in the wildland urban interface or in condition class two or three in Fire Regime I, II or III outside of WUI.
- Treatment activities would not be proposed in wilderness areas or in wilderness study areas if the activity would impair the suitability of the study area.

Forest plan standards and guidelines, other resource management plans, and any other legally applicable direction still had to be met if the new CE's were used. Projects developed with the new categorical exclusions also needed to be identified through public processes in collaboration with; the State, local governments, Tribes, community based groups, and private landowners as well as other interested parties.

Bitterroot Community Based Wildland Fire Risk Mitigation Plan

During the winter of 2002 - 2003 the Bitterroot Community Based Wildland Fire Risk Mitigation Plan for Ravalli County was developed. The plan development followed the collaborative framework outline in the August 2001 document "A Collaborative Approach for Reducing Wildland Fire Risks to Communities and the Environment, a 10 Year

Comprehensive Strategy and Implementation Plan" (USDA Forest Service, USDI Bureau of Land Management, 2001). The Bitterroot National Forest actively collaborated with six working groups in Ravalli County. The fuel reduction group identified the Hayes Creek area as one of the high priority areas within the Hamilton Rural Fire District needing hazardous fuel reduction on both private and national forest land.

DESIRED CONDITION

Overall, the desired condition within the project area was to create an open canopy of residual trees where fire behavior would be altered. The threat of fire was from private land onto national forest land and from national forest land onto private land. Adjacent to private land the canopy openings would be the greatest, fire risk would be significantly reduced and this area would provide a safe place from which suppression activities would occur. Further away from private land, canopy openings would be more moderate and allow for changes in fire behavior, while still optimizing big game winter range habitat. Fire killed snags and down woody debris would be maintained across the landscape approximating historic conditions.

Healthy ponderosa pine would be the dominant species at lower elevations with a transition to a mix of species as elevation increased. Average size of trees would be larger but there would be fewer trees per acre. The landscape would be predominately lightly forested and single storied with scattered pockets of regeneration. Insect and disease infestation would occur at endemic levels. Aspen vegetation would begin to be rejuvenated through human created disturbance processes.

SILVICULTURE PRESCRIPTIONS

Thinning

Thinning from below to a designated spacing was the main treatment prescribed. Fire risk would be greatly reduced along the residential/wildland interface boundary for 500 feet in width in unit A (refer to figure 2), where treatment prescriptions created very open canopy conditions through a 40 x 40 foot spacing across all size classes. Further away from private land, units B1, B2, D, Z, X2 (refer to figure 2), canopy openings would be moderated yet still allow for changes in fire behavior with a 20 x 20 foot spacing across of size classes. Losses from prescribed fire and from future wildfires would be within acceptable limits and would not result in large scale losses of existing vegetation.

Thinning would reduce stocking levels and increase the water and nutrients available for residual trees resulting in increased individual tree health and vigor. Conifer trees, aspen trees and apple trees would all benefit from an increase in available water and nutrients.

Ponderosa pine would be favored as much as possible, retaining on site a more resilient fire adapted species. In addition, since ponderosa pine was more resistant to Armillaria, retaining more pine on site would lessen the vegetation impacts resulting from the root disease. At higher elevations where a mix of species currently exists, a diversity of tree species would still be retained.

More open canopy conditions would allow for an increase in the amount of browse and foraging species favored by big game animals. Changes in canopy density would also allow for easier foraging (flying through the canopy) for goshawks (*Accipiter gentiles*) as well as an increase in its prey base (small animals) resulting from an increase in the browse component. Flammulated owl habitat does not currently exist, however thinning done now would allow for residual trees to grow larger and set the stage for creating the desired flammulated owl habitat.

Single Tree Selection

Single tree selection was prescribed for unit X1 (refer to figure 2). The vegetation composition within this treatment unit was different than the other treatment areas thus the need for a different prescription. The objective of using a single tree selection was to target for removal the majority of the Douglas-fir trees within a certain diameter range and remove all lodgepole pine to slowly change the vegetative composition back to more predominately ponderosa pine. No commercial size ponderosa pine would be removed in this unit.

Unit X2 (refer to figure 2) was a combination treatment unit including thinning across all size classes of ponderosa pine and single tree selection removing Douglas-fir within a limited diameter range and removal of all lodgepole pine. Treatments within both of these units would meet the fuel reduction and fire risk objectives as well as provide for a diversity of habitat for big game animals.

Slashing

The intent of slashing was to completely remove the ladder fuel component (non commercial size trees) to address the fire risk and fire behavior objectives. Slashing would occur within units X1 in conjunction with single tree selection, within unit C and unit Y, and riparian areas (refer to figure 2). Slashing was the only treatment prescribed within units C and Y which reflected the need based on the vegetative condition. Within riparian areas, the objective of slashing was to remove the smaller size trees that were competing with the aspen and cottonwood trees. All slashed material would be lopped and scattered, and/or piled and piles burned as needed.

Activity Fuel Treatments

Many options were available for treatment of activity fuels. One treatment prescribed that all ponderosa pine material greater than three inches in diameter had to be removed off site, chipped, or piled. The objective was to deal with the three inch and greater material that had the potential to be the catalyst for Ips insect problems.

Lop and scatter of ponderosa pine less than three inches in diameter and lop and scatter of all other tree species of non-commercial size was also utilized. This treatment allowed us to treat the non-commercial ladder fuel component found throughout the area.

Hand piling and burning piles of heavy fuel concentrations was another treatment prescribed. This treatment was specifically prescribed along the recreation trail and along the only access road to reduce risk of a fire start adjacent to these heavily used areas. This treatment could also be initiated on an as need basis within other parts of the project area.

Prescribed Fire

Given that this area historically had a fire regime of frequent fires of low to mixed severity, we wanted to begin the process of returning fire to the site. We also recognized that this meant repeated entries of fire at fairly regular intervals. The commercial treatments, understory ladder fuel treatments and activity fuel treatments would help us be successful with our first entry of prescribed fire. Prescribed fire would also serve as the second disturbance element to help rejuvenate the aspen trees. Within riparian areas prescribe fire would be the only disturbance. The vision for prescribed fire treatments would be a mosaic of burned and unburned areas with minimal residual tree mortality.

METHODS: IMPLEMENTATION

A variety of tools were available for implementation and the one that best fit our need was the new stewardship contract. In addition, approval to utilize stewardship contracting had to be granted by the Regional Forester. The forest timber sale contracting officer, as well as regional timber administration personnel were supportive of the project and instrumental in obtaining the Regional Foresters approval.

STEWARDSHIP CONTRACTING

Integrated Resource Service Contract - Renewable Resources Handbook Direction

There were two types of stewardship contracts available for use. For this project, the value of the timber (receipts) would not be enough to pay for all the service work the project proposed, so our choice was to use the Integrated Resource Service Contract (IRSC). The IRSC allowed us to trade goods for services, obligate appropriated money to the contract as well as use receipts from other stewardship contracts to help pay for the project work. This type of contract gave us the flexibility we needed to find ways of accomplishing the work on the ground. The following is a brief list of options outlined in the stewardship contracting handbook (USDA Forest Service, 2005) that were applicable to our project:

- Stewardship contracts may be selected on a best value basis, contracts may use a performance-based format to meet end result objectives, and the of the service contract length may exceed five years but must not exceed 10 years.
- The Forest Service unit may apply the value of timber or other forest products removed as an offset against any services received.
- Designation and marking of trees, portions of trees, or special forest products may be done by persons not employed by the Secretary of Agriculture in accordance with the 16 U.S.C. 2104 Note.
- Monies received from the sale of forest products or vegetation removed under a stewardship contract may

be applied at the project site or at another stewardship contracting project site without further appropriation.

- Treatment units analyzed and approved in other NEPA documents could also be included within a single stewardship project.

FUNDING SOURCES

We needed to infuse additional appropriated money into the project to help pay for the all service work designated in the contract. This additional money supplemented the receipts from the product removal and allowed for the full range of work to be accomplished. Hazardous fuel money from forest funds contributed $55,000. Forest Health Protection funds of $113,250 were successfully competed for and contributed to the project. These two supplemental funding sources were specifically designated for our project and obligated in the service contract.

CONTRACT PROCEDURES

Contract Preparation

Preparation of the integrated resource service contract occurred early in the spring of 2004. Several district resource personnel were involved with writing the specifications for the service portion of the contract as well as reviewing the timber sale provisions relating to timber removal. The contract had a schedule of work that included base items which were mandatory and elective work items. The elective work items were an indefinite quantities delivery item and could be initiated at the governments discretion based on need. In addition, the contract included an equipment rental rate bid item which could be initiated by the government for work on an as need basis. Task orders would be issued identifying all work to be accomplished.

The contract utilized designation by description for the cutting of trees (USDA Forest Service, 2005). This meant that the contractor would determine, on the ground, the material that would be removed. The designation by description was documented in the silviculture prescriptions which became part of the official IRSC. The description for cutting of trees needed to be based on characteristics that could be verified after the material was cut and removed. This method was used since it was the most efficient means of designating material for removal (minimizing tree marking by agency personnel) and because several individuals applying the description on the ground would arrive at the same end result. Inspection procedures outlined in the contract ensured that the material removed was verifiable and accountable.

We added four units, called the Waddell units, to the stewardship contract that were in need of treatment but analyzed under a different decision memo. The material to be removed in these four units was mainly saw log size with a lesser amount of service work as compared to the Hayes Creek units. The inclusion of the Waddell units gave us additional timber volume and thus value, that helped offset the cost of the service work over the entire contract area.

Mitigation items outlined in the Decision Memo were incorporated into the treatment prescriptions and the contract language. These added to the complexity of the work and included:

- Retention of visual leave islands; visual islands were marked on the ground by the wildlife biologist to address site distance concerns within the designated winter range management area. No treatment would be allowed within these leave islands.
- Thinning variance; a thinning spacing variance of 25 percent was allowed.
- Operational restrictions; operations would not be allowed on weekends and would only be permitted between dawn and 6:00 P.M daily. This allowed the recreation trail to be used in the evening and on weekends.
- Restricted season of work; season of work was designation from August 15 to November 15 to address Ips beetle concerns.

Contract Solicitation and Acceptance

Our contract solicitation was an indefinite quantities indefinite delivery, firm fixed price for contract services with provisions for timber removal. The solicitation was a request for proposal solicitation. Each prospective contractor had to submit a technical proposal telling the government how they planned to accomplish the work to meet the treatment prescription. Details of what should be addressed in the technical proposal included a list of equipment to be used, key personnel and subcontractors, a plan of operations, and price to be paid for included timber.

During the contract solicitation period, the district held a “show me” field trip for prospective contractors. The trip was a chance to discuss the treatments, the stewardship contract and technical proposal process. We had a follow up office meeting to answer additional questions.

3a – Feller buncher. 3b – Stroke delimber processing at landing

Figure 3a and 3b— Hayes Creek fuel reduction project, logging in progress. Photos by Kim Johnson

A panel of agency personnel assessed the submitted proposals to determine the ability of a prospective contractor to perform the work. When a proposal was selected, questions resolved and items negotiated, the contract award was made. The contractor’s proposal became part of the contract.

The selected proposal presented a different method for accomplishing the work than what we anticipated would occur. The proposal outlined using whole tree yarding and a feller buncher to cut and bunch material along designated skid trails. The proposal also included cutting the small size non commercial material and hauling this material to the landing. Cutting and hauling all material meant the landing size would be larger than anticipated and the piles at the landing would also be very large. We verified with other resource personnel that there were no additional issues associated with this change and that the intent of the project would still be met. Landing size and location was dealt with through contract administration. The landing pile size description in the contract was changed to address the potential Ips issue and the contract modified accordingly. The landing piles had to a minimum of 20 feet wide and 10 feet in height and would serve as beetle sinks, attracting local beetle populations. The intent was to keep the beetles within the pile, using the piled material as a breeding ground and not our residual standing trees.

Contract Inspections

Inspection of the treatment implementation would be done by the Contracting Officers Representative or harvest inspector. If problems surfaced, it would be dealt with through the contract process and immediate resolutions and adjustments made to the contract as needed.

HARVEST ACTIVITIES

Work began on the project in August of 2004 within unit Z and the portion of unit A that was immediately adjacent to unit Z (refer to figure 2). Thinning was accomplished using a feller buncher (refer to figure 3a) and a rubber tired skidder hauled the cut and bunched material along designated skid trails to a designated landing. Approximately 160 acres were treated between these two units with 10 landings designated and utilized for processing. At the landing a stroke delimber processed each tree, removing the branches and cutting the tops off into the landing pile (figure 3b). The remaining piece was then cut and sorted into pulpwood or commercial size material. The contractor hauled the pulpwood and commercial size material to the mill and the residual tops and limbs became the large landing piles. To date, units X1, X2, and one portion of unit A still need to be treated through the contract. Units C and Y will be done with forest service crews since the treatment prescribed was slashing with no commercial component.

RESULTS

Fulfilling the Desired Objectives

Vegetation Objectives

Decreased Fire Risk

The main treatment prescribed to meet the fuel reduction objectives was thinning from below across all size classes. Adjacent to private land a very open canopy was desired with the intent of changing fire behavior and providing a safe place for firefighters. Crown fires would drop to the ground and become surface fires that were more safely and successfully attacked. Crown fire would also not be able to be initiated within this area. In addition, the reduction

4a – Before treatment. 4b – After treatment.

Figure 4a and 4b— Vegetative conditions before and after treatment in unit A. Thinning from below to a 40 by 40 foot spacing prescribed. Photos by Kim Johnson

of hazardous fuels and potential for large fire spread from national forest land to private land and from private land to national forest land would be greatly reduced. Figures 4a and 4b display the before and after treatment vegetative condition within unit A where a 40 by 40 foot spacing was prescribed.

Further away from private land, the intent of the treatments was to still change fire behavior however this change would not be as significant as the change adjacent to private land. These areas thinned to 20 by 20 foot spacing, would have a more moderated canopy opening and torching of single or groups of trees would still occur during a fire event. Figures 5a and 5b display the before and after treatment vegetative condition within unit Z. Overall within both treatment areas, ladder fuels were greatly reduced and canopy openings created at varying levels.

Field trips during and after treatments have included several fire personnel from the forest and district level. A comment from this group was that they prefer the very open thinning treatment of unit A, 40 and 40 foot spacing (figures 4a and 4b), over the moderated thinning treatment in unit Z (figures 5a and 5b). The change in fire behavior specific to various treatment prescriptions was a conscience choice during planning and project design. Since then personnel changes have occurred and with those changes come differing opinions. Overall, the project objectives were met within these units. Now that treatments can be seen on the ground we will need to use this example for discussion and development of future fuel reduction projects.

Decreased Insect and Disease Risk

Another objective of thinning was the reduction of stand densities (figures 4a and 4b, figures 5a and 5b) and the resulting increase in the amount of nutrients and water available to the residual vegetation, thus increasing individual tree health and vigor. It is too soon to tell if tree health has increased based on width of tree rings and leader growth. Informal checks of the treated area indicate that a minor amount of mortality due to Ips infestations has occurred since thinning was accomplished.

Aspen Rejuvenation

Aspen pockets outside the riparian areas were allowed to be disturbed through the thinning and prescribed burning operations. Most of the thinning treatments have been completed however none of the prescribed fire treatments have occurred. It is too soon to tell if we have been successful in rejuvenating the aspen vegetation.

Apple Tree Protection

The prescriptions called for minimizing damage to the residual apple trees. Since it was difficult to quantify what minimal damage meant and design a specific contract provision, we had discussions with the contractor at the contract pre-work and in the field explaining that our intent was. We did not want the apple trees to be intentionally run over nor have skid trails run through them if possible. However, we recognized some

5a – Before treatment. 5b – After treatment.

Figure 5a and 5b— Vegetative conditions before and after treatment in unit Z. Thinning from below to a 20 by 20 foot spacing prescribed. Photos by Kim Johnson damage would occur during treatment operations. Once the contactor saw the apple trees on the ground and listened to our concerns, they were very willing to work with the forest to ensure minimal damage occurred. It is too soon to tell if our thinning treatments have enhanced the overall health of the remaining apple trees however, at the time of this writing, some of the apple trees are producing fruit.

6a – Trail before treatment. 6b – Trail after treatment resolution.

Figure 6a and 6b— Coyote Coulee recreation trail before and after vegetative treatment activities occurred. Photos by Kim Johnson

Wildlife Objectives

Current research regarding big game habitat needs in winter range focuses more on forage availability than thermal cover however, both issues were addressed (Lockman, 2007). Creating a less dense canopy through thinning treatments would increase the diversity of plant communities available as forage for big game animals. Riparian Habitat Conservation Areas, designated in the project design to address fisheries issues, also functioned as untreated thermal cover corridors for big game. While we feel the objective was met, it will be several years before we start to see a change in plant community diversity.

The visual leave islands addressed sight distance concerns during hunting season and also served to maintain small patches of habitat diversity as well as some structural diversity throughout the area.

The active goshawk nest location was considered during the project design and an area adjacent to the nest site was not treated. The district wildlife biologist (Lockman, 2007) commented that while the project area was not goshawk nest habitat, it did provide foraging habitat. Thinning treatments would reduce stem densities, specifically of the understory vegetation. Plant community diversity would increase with a reduction of tree stems which would in turn increase the diversity of wildlife species available for foraging goshawks. It will be several years before we actually begin to see this change.

The wildlife biologist also commented that thinning treatments in the low elevation ponderosa pine vegetation type will help set up the trajectory to provide for future flammulated owl habitat. Habitat for flammulated owls (*Otus flammeolus*) does not currently exist within the project area. By favoring ponderosa pine trees and reducing stocking levels, residual tree health and vigor would be increased. At some point in the future, a healthy mature to old growth ponderosa pine forest with snags, desired by flammulated owls will result.

Human Need Objectives

Recreation Trail

The original prescriptions were no different along the recreation trail than within any other portion of the treatment units. Figure 6a shows the vegetation along the trail prior to treatment. One stakeholder group expressed concern over the open forest appearance along the recreation trail after some of the treatment had occurred. The district and the contractor worked with the group to reach a favorable resolution. The resolution changed the treatment along the trail. Instead of thinning from below, a 50 foot semi-treated buffer along each side of the trail would occur. For 25 feet in width on each side of the trail no trees would be removed and within the next 25 feet only the commercial size trees would be removed. Figure 6b shows the vegetative condition trail after the treatment change. This left a more densely stocked area adjacent to the trail and a less stocked area further away. The stakeholders were told that if a fire event occurred, the trail corridor vegetation would most likely suffer extensive damage because the tree canopy was not opened up and ladder fuels still existed. They were willing to accept this risk. Addressing their concerns and reaching an agreeable resolution was important to the group.

External and Internal Relationships

During implementation, we worked with an adjacent landowner who had expressed concerns about the large landing piles (refer to figure 7). He understood the concept

Figure 7— Hayes Creek fuel reduction project, large landing piles.
Photo by Kim Johnson

of the large piles acting as beetle sinks, but was afraid the beetles would still come out of the piles and attack trees on his property. To address his concerns, we pursued additional protection at the three large landing piles closest to his property and installed funnel traps to catch the stray beetles. The funnel traps were installed prior to the 2005 spring emergence of the beetle and were monitored weekly during the spring and summer beetle flight season. What we accomplished with the funnel traps was difficult to assess with any degree of certainty. Responding to the adjacent landowners concerns and maintaining good relationships far outweighed any benefit the funnel trapping may have provided.

A main component of our implementation success was the upfront willingness of our contractor to do a good quality job. In that regard they asked questions for clarification and took time out while running harvesting equipment to talk with the public and agency personnel who visited the project site. They fostered a good working relationship with the agency when issues and concerns arose by helping to reach solutions.

Another part of our success was attributed to the support of the Region and Forest for assisting us as requested during the contract preparation and solicitation process. Since the IRSC was a new format and untested on our forest, it presented challenges to agency personnel as well as prospective contractors. Regional and Forest timber administration specialists worked with us and prospective contractors to answer questions and resolve concerns.

Interpretative Kiosk Benefits

Fund received from our Forest Health Protection proposal included not only thinning dollars, but also money to design and install a three panel interpretive kiosk at the Coyote Coulee trailhead, the recreation access to the trail within the project area. The intent was to provide basic information to the public about forest ecology and why the need for treatment in the Hayes Creek area. Figure 8 shows the three panel kiosk. One panel presented information on fires historic role in the forest and how the forest has changed over time. Another panel presented information and a map of the coyote coulee trail winding through the project area. The last panel displayed the proposed treatments for the project with photos of similar work done that would provide an example of how the treatment in Hayes Creek would look. Other trail information and notices could also be posted at the kiosk.

Economic Benefits

Product removal for the contract was measured in tons. The cruise volume for the Hayes Creek units was approximately 5115 total tons, for an average of 12 tons per acre.[1] This translated into a total of 1650 hundred cubic feet (CCF) and an average of 3.75 CCF per acre or a total of 825 thousand board feet (MBF) and an average of 1.85 MBF per acre. These figures only included commercial size material.

The stewardship contract allowed for the removal of additional material “subject to agreement”. At the contractor’s request, we made an agreement that allowed them to remove pulpwood material from the project area. This agreement was a win-win situation because more material was utilized as product and not left in landing piles. With the addition of the pulpwood material, the amount of material removed to date almost equals the amount of material offered in the service contract solicitation.

The Fuels for Schools program in Darby, Montana, also benefited from our project.[2] Receipts from other stewardship projects, $12,485, were designated to pay for the chipping

[1] Timber cruise volume estimates (2004) for the Hayes Creek Fuel Reduction Project are on file at the Bitterroot National Forest, Darby Ranger District.

[2] The fuels for schools program is sponsored by the USDA Forest Service and is designed to convert unmarketable material from thinning and logging into low cost heat for schools.

Figure 8— Interpretive kiosk at Coyote Coulee trailhead. Photo by Kim Johnson

of residual slash from three large landing piles and hauling this chipped material to the Darby school. This work was done in the winter of 2005 - 2006. Approximately 383 tons or 12 log truck loads were hauled to the school. The amount of material chipped and hauled would provide heat for the school for approximately half a winter.

Lastly, $7340 of receipts from other stewardship projects on the forest was transferred into the project. That money helped supplement the other appropriated funding so additional work could be accomplished.

DISCUSSION

Lessons Learned

This project was very challenging and we learned many lessons while working through the entire process. A mix of appropriate agency personnel need to be involved during various phases of the project. It is best to have them involved up front rather than after the fact.

Having an open mind and being responsive to different ways of accomplishing the work was critical to our success. This meant modifying and tweaking treatment prescriptions while still meeting the intent of the fuel reduction objectives.

We faced many bumps and hurdles along the way. Addressing and solving the problems was not difficult but time consuming and required us to come up with creative and innovative solutions.

We found that we improved and maintained our working relationships with stakeholders, individual land owners and the contractor by working in a collaborative effort that allowed us to deal with conflicts and find solutions that were acceptable to all interested parties.

Accomplishing our fuel reduction treatments was not an easy task. It took considerable time, energy and commitment from agency personnel. Having the proper attitude to work through problems and find creative solutions was the key ingredient. This led to a sense of accomplishment and made for a very rewarding experience.

CONCLUSIONS

Being able to share and showcase a successful fuel reduction project was the goal of this paper. The phrase "timing is everything" certainly sums up our success. We were able to take advantage of all the tools in the toolbox from utilizing a new categorical exclusion for planning to implementation through the use of a stewardship contract. The project required commitment, innovative thinking and creative solutions to problems. It required us to be receptive to different ways of doing business. Lastly we had to be willing to work with a variety of people, internal and external, to gather as much support as possible to be able to implement the treatments. Being successful with this project will set the stage for being successful with future fuel reduction projects.

ACKNOWLEDGEMENTS

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Long-Term Basal Area and Diameter Growth Responses of Western Hemlock-Sitka Spruce Stands in Southeast Alaska to a Range of Thinning Intensities

Nathan J. Poage

ABSTRACT

To better understand the long-term basal area and diameter growth response of young, well-stocked, even-aged, mixed-species stands of western hemlock (*Tsuga heterophylla* (Raf.) Sarg.) and Sitka spruce (*Picea sitchensis* (Bong.) Carr.) to a range of thinning intensities (heavy, moderate, light, and unthinned), 20 years of post-treatment (i.e., thinning) data were analyzed from 128 permanent study plots at 32 installations in southeast Alaska. Thinning significantly increased the basal area growth of the thinned plots relative to that of the unthinned plots. Basal area growth of the thinned plots decreased with increasing thinning intensity, likely a consequence of the reduction in growing stock with increasing thinning intensity. Diameter growth increased with increasing thinning intensity. Younger stands (typically with smaller pre-treatment basal areas and diameters) responded more vigorously to thinning than did older stands, as did stands growing on more productive sites. The models developed in this analysis can be used by land managers to make general predictions of how western hemlock-Sitka spruce stands similar to those investigated in southeast Alaska are likely to respond to different thinning intensities in terms basal area and diameter growth during the first 20 years post-treatment.

Keywords: *Picea sitchensis*, southeast Alaska, thinning, Tongass, *Tsuga heterophylla*, young stand growth.

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INTRODUCTION

The majority of the forests along the North American Pacific Northwest coast are mixed-species stands containing a significant proportion of western hemlock (***Tsuga heterophylla*** (Raf.) Sarg.) and, to a lesser degree, Sitka spruce (***Picea sitchensis*** (Bong.) Carr.), western redcedar (***Thuja plicata*** Donn), yellow cedar (***Chamaecyparis nootkatensis*** [D. Don] Spach), and mountain hemlock (***Tsuga mertensiana*** (Bong.) Carr.). Spanning over 22^{o} of latitude, coastal hemlock–spruce forests occur from northern California to south-central Alaska, a distance of more than 1500 miles (Harris 1990). Low respiration demands associated with cool temperatures and abundant precipitation throughout the year in these coastal forests have led to some of the highest recorded accumulations of above-ground biomass in the world (Waring and Franklin 1979).

Mixed-species stands of hemlock and spruce regenerate naturally following harvesting and heavy thinning in southeast Alaska (Ruth and Harris 1979, Deal and Farr 1994, Zasada and Packee 1994, Deal and Tappeiner 2002, Deal et al. 2002). In southeast Alaska, harvesting of primary forest has led to the establishment of an estimated 649,000 ac of western hemlock–Sitka spruce young-growth stands since the 1950s (Barbour et al. 2005). Interest in actively managing these naturally regenerated young-growth stands led, in the early 1970s, to the initiation of the USDA Forest Service's Cooperative Stand-Density Study (CSDS; DeMars 2000).

A primary objective of the CSDS is addressed in this paper: to understand the long-term basal area and diameter growth responses of young, well-stocked, even-aged, mixed-species stands of western hemlock and Sitka spruce

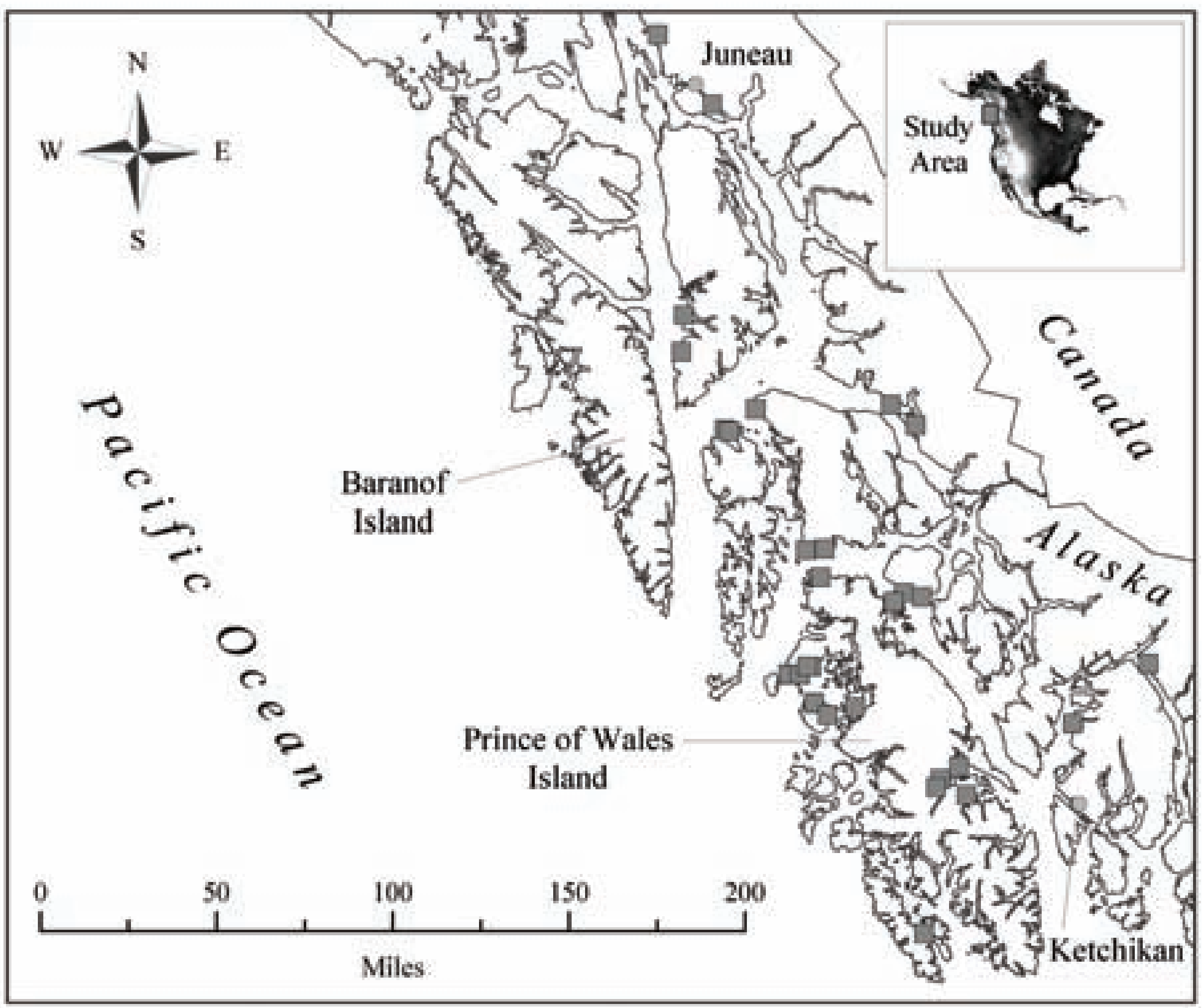

Figure 1— Locations of the 32 Cooperative Stand Density Study installations (red squares) discussed in detail in this paper.

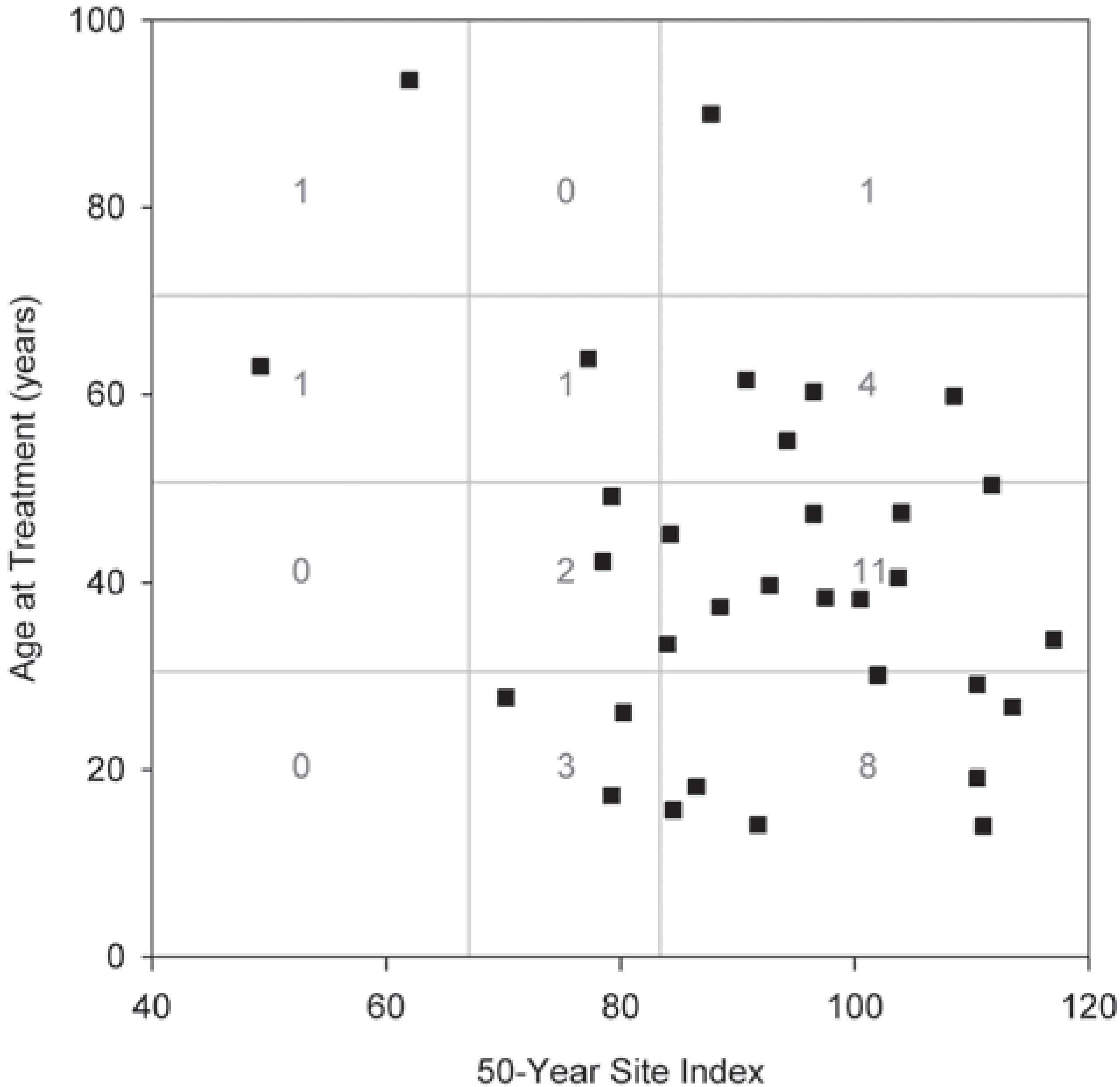

Figure 2— Mean age at treatment over 50-year site index (Farr 1984) for 32 installations in southeast Alaska. Gray lines indicate the breaks between the 4 age classes and 3 site index classes defined in the original study plan for the Cooperative Stand Density Study (Farr 1976, DeMars 2000). Gray numbers indicate the number of installations (out of 32) occurring in each of the original 12 combinations of age at treatment class × site index class defined in the original study plan.

in southeast Alaska to a range of thinning intensities (Farr 1976, DeMars 2000). Of particular interest is to better understand how the basal area and diameter growth responses are influenced by age and stand structure at the time of thinning and site productivity (site index).

METHODS

Twenty years of post-treatment (i.e., thinning) data were analyzed from 128 permanent study plots (96 thinned plots and 32 unthinned plots) maintained by the USDA Forest Service at 32 sites or installations in southeast Alaska (Figure 1). The north-to-south distribution of the plots was approximately 250 mi. Most plots were located close to the coastline at elevations of < 500 ft. All plots were located in the *Picea sitchensis-Tsuga heterophylla* forest type (Franklin and Halpern 2000). More than 95% of total basal area at each plot was made up by hemlock and spruce. The stands containing the plots were between 13 and 94 years old at the time of plot establishment; 50-year site index (Farr 1984) ranged between 49 and 118 (Figure 2). Pre-treatment basal areas (**BA**) were between 34 and 407 ft2/ac; pre-treatment quadratic mean diameters (**QMD**, the diameter of tree of average basal area) were between 1.2 and 16.3 in. DeMars (2000) provides a more detailed description of the study area.

All installations meeting 2 criteria were selected for analysis. First, the plots at each installation had measurements made on live trees for least 20 years of post-treatment measurements (generally made every 2–4 years). Second, an installation comprised 1 unthinned "control" (**C**) plot, 1 lightly (**L**) thinned plot, 1 moderately (**M**) thinned plot, and 1 heavily (**H**) thinned plot. Thirty-two installations (96 thinned and 32 unthinned plots) met these selection criteria.

All plots were square, 0.2 ac in size, and centered in the middle of a 1.0 ac treated area (Farr 1976, DeMars 2000). Each thinned plot was thinned once from below at plot establishment, generally to a uniform spacing. Pre-treatment **QMD** and thinning guidelines included in the CSDS study plan (Farr 1976, DeMars 2000) were used to determine post-treatment **BA** and **QMD**, average spacing, and number of trees per acre (**TPA**) for the **L**, **M**, and **H** thinning treatments. Preliminary analysis of the thinning guidelines indicated that the **L**, **M**, and **H** thinning treatments reduced stand density—expressed in terms of either relative density (Curtis 1982) or maximum stand density index (Poage et al. 2007)—to approximately 50% (**L**), 35% (**M**), and 25% (**H**) of full stocking (Figure 3).

Species and diameter at breast height (dbh, the diameter at 4.5 ft above the ground) were recorded for each live tree with a dbh > 0.5 in within each plot immediately pre- and post-treatment (i.e., at 0 years since treatment). Exceptionally dense young stands (generally greater than 1500 trees/acre) were sub-sampled using nine 0.004 ac circular subplots spaced at 23.3 ft intervals on a 3 x 3 grid. All trees measured at plot establishment were tagged. For each plot, total and species-specific **BA**, **TPA**, and **QMD** were calculated pre- and post-treatment (i.e., at 0 years since treatment) and for the measurements closest to 5, 10, 15, and 20 years since treatment. Stand age and site index were determined at the time of treatment (DeMars 2000). DeMars (2000) provides additional details about the plot design and sampling scheme.

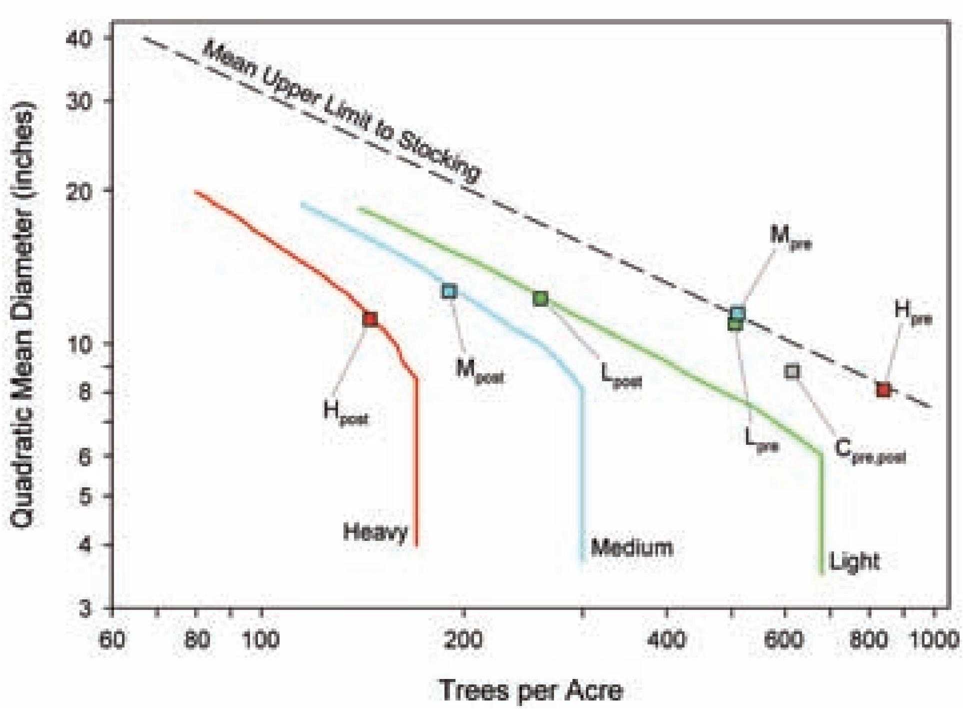

Figure 3— Thinning guidelines defined in the original study plan for the Cooperative Stand Density Study (Farr 1976, DeMars 2000). Post-treatment quadratic mean diameters and trees per acre are shown for lightly (L) thinned plots in green, moderately (M) thinned plots in blue, and heavily (H) thinned plots in red. To illustrate, the squares indicate the pre- and post-treatment quadratic mean diameters and trees per acre for the 4 plots at one installation. The dashed black line labeled Mean Upper Limit to Stocking represents the mean maximum stand density index (SDImax = 619) recently identified for western hemlock–Sitka spruce stands in southeast Alaska (Poage et al. 2007).

How **BA** and diameter (**QMD**) growth responses during the 20 years post-treatment were influenced by thinning intensity, age when thinned, pre-treatment **BA**, pre-treatment **QMD**, site index, and years since treatment was modeled using a repeated measures approach and the **PROC MIXED** procedure of SAS (2003). Restricted/residual maximum likelihood (**REML**) was selected as the estimation method.

Backwards, stepwise selection of explanatory variables resulted in the final mixed models for **BA** and **QMD** shown in Equation 1:

$$
\begin{aligned}
y_{jkt} = {} & (\beta_0 + \beta_1 BA_{pre,jk} + \beta_2 QMD_{pre,jk} + \beta_3 SI_{jk} + \beta_4 L_{jk} + \beta_5 M_{jk} + \beta_6 H_{jk}) + \\
& time \times (\beta_7 + \beta_8 QMD_{pre,jk} + \beta_9 SI_{jk} + \beta_{10} L_{jk} + \beta_{11} M_{jk} + \beta_{12} H_{jk}) + \\
& b_j + e_{jkt}
\end{aligned}
$$

where y_{jkt} is the BA or QMD of plot k of installation j in year t,

$BA_{pre,jk}$ is the pre-treatment BA of plot k on installation j,

$QMD_{pre,jk}$ is the pre-treatment QMD of plot k on installation j,

SI_{jk} is the 50-year site index of plot k on installation j,

L_{jk}, M_{jk}, and H_{jk} are indicator variables that take the value of 1 if plot k of installation j received the light, medium, or heavy thinning treatment, respectively, and 0 otherwise,

$time$ is year t since the thinning treatment,

b_j is the random effect of installation j, and

e_{jkt} is the random error.

It is assumed that b_j is normally distributed with mean 0 and variance $\mathrm{Var}(b_j) = \sigma_b^2$. The vector of errors of the t observations from plot k of installation j, $\mathbf{e}_{jk}$, is assumed to be normally distributed with mean $\mathbf{0}$ and covariance matrix $\mathrm{Var}(\mathbf{e}_{jk}) = \mathbf{\Sigma}$. It is further assumed that b_j and $\mathbf{e}_{jk}$ are independent and that observations from different installations are also independent

Note that Equation 1 is structured to highlight the variables associated with the immediate post-treatment **BA** or **QMD** (i.e., the intercept term) in the first row, the variables associated with the change in **BA** or **QMD** over time (i.e., the slope term) in the second row, and the error terms in the third row.

RESULTS AND DISCUSSION

The plots responded to thinning as one might have predicted. Thinning significantly increased the basal area (**BA**) growth of the thinned plots relative to that of the unthinned plots, but **BA** growth of the thinned plots decreased with increasing thinning intensity (Figure 4, Table 1). The highest **BA** growth was observed in the lightly (**L**) thinned plots. **BA** growth of the **L** plots was, on average, 2.18 ft^2/ac/yr greater than that of the unthinned, control (**C**) plots (see β_{10}, the time × **L** parameter estimate for the **BA** mixed model in Table 1). Average **BA** growth of the moderately (**M**) and heavily (**H**) thinned plots was 1.68 ft^2/ac/yr and 1.16 ft^2/ac/yr greater, respectively, than that of the **C** plots (see β_{11} and β_{12} for the **BA** mixed model in Table 1). The observed decrease in **BA** growth with increasing thinning intensity was likely a consequence of the corresponding reduction in growing stock with increasing thinning intensity. Although the **BA** growth of individual trees was greater in heavier thinnings than in lighter thinnings, too few trees were retained in heavier thinnings to generate the same plot-level **BA** growth observed in lighter thinnings.

In contrast to the **BA** growth of plots, diameter (**QMD**) growth increased with increasing thinning intensity (Figure 5, Table 1). Thinning significantly increased the **QMD** growth of the thinned **M** and **H** plots compared to that of

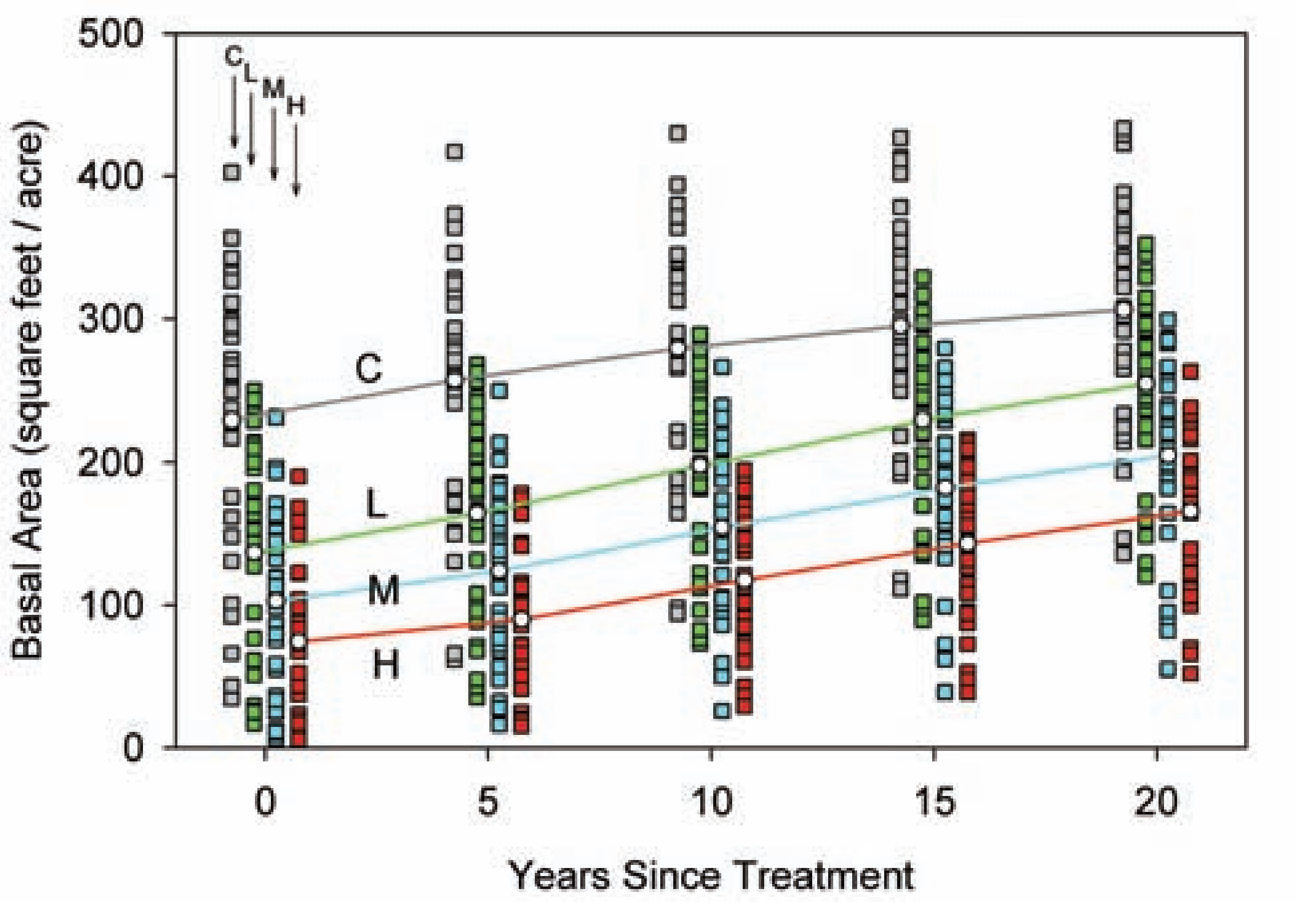

Figure 4— Plot-level basal area data shown by treatment at 0, 5, 10, 15, and 20 years since treatment. Data for unthinned "control" (C) plots are shown in gray, lightly (L) thinned plots in green, moderately (M) thinned plots in blue, and heavily (H) thinned plots in red. White circles indicate the average basal areas for each treatment at 0, 5, 10, 15, and 20 years since treatment.

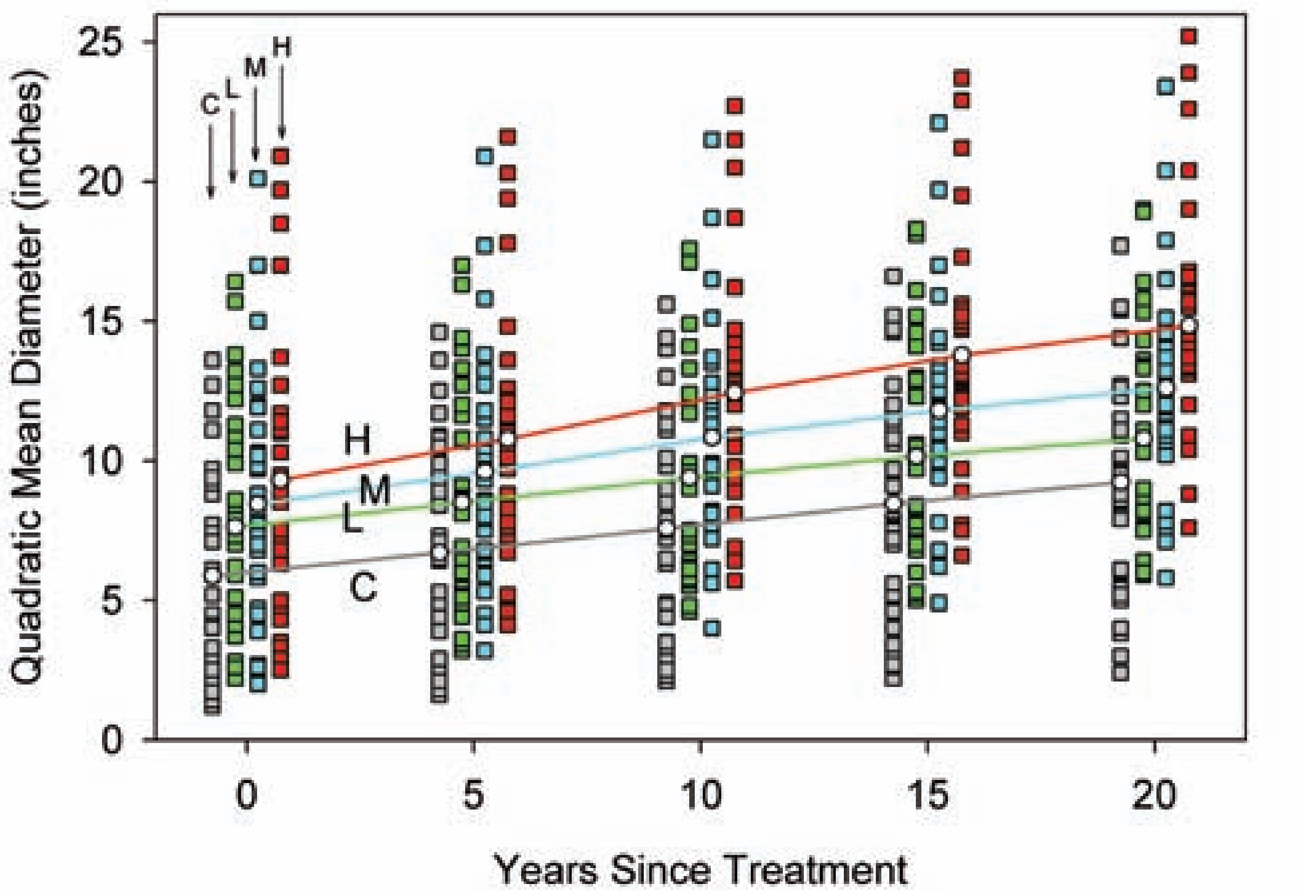

Figure 5. Plot-level quadratic mean diameter data shown by treatment at 0, 5, 10, 15, and 20 years since treatment. Data for unthinned "control" (C) plots are shown in gray, lightly (L) thinned plots in green, moderately (M) thinned plots in blue, and heavily (H) thinned plots in red. White circles indicate the average quadratic mean diameters for each treatment at 0, 5, 10, 15, and 20 years since treatment.

the unthinned **C** plots. Average **QMD** growth of the **M** and **H** plots was 0.03 in/yr and 0.09 in/yr greater, respectively, than that of the **C** plots (see β_{11} and β_{12} for the **QMD** mixed model in Table 1). Average **QMD** growth of the **L** plots was not significantly different than that of the **C** plots.

Younger stands responded more vigorously to thinning than did older stands, as did stands growing on more productive sites. Both **BA** and **QMD** growth decreased with increasing pre-treatment **QMD**, pre-treatment **BA**, and age when thinned. Age when thinned, pre-treatment **QMD**, and pre-treatment **BA** were all positively correlated (i.e., an older plot typically had a larger **QMD** and more **BA** before thinning than a younger plot). The positive correlations between these three explanatory variables resulted in age when thinned being dropped as an explanatory variable from the final models for both **BA** and **QMD** (Equation 1). Both **BA** and **QMD** growth increased with increasing site index (see β_9 for the **BA** and **QMD** mixed models in Table 1).

The models developed for **BA** and **QMD** can be used by land managers to make general predictions of how western hemlock-Sitka spruce stands similar to those investigated in southeast Alaska are likely to respond to different thinning intensities in terms **BA** and **QMD** growth during the first 20 years post-treatment. To illustrate, consider a 40-year-old stand with a pre-treatment **BA** of 275 ft^2/ac, a pre-treatment **QMD** of 6.5 in, and an estimated 50-year site index of 85. Equation 1 can be used to compare how, for example, the **BA** of this stand might develop over 20 years if it were a) lightly thinned and b) heavily thinned.

Table 1. Parameter estimates for the final basal area and diameter mixed models (Equation 1). With the exception of those parameter estimates indicated as not significant by the "n.s." superscript, all parameter estimates were significantly different than zero ($p < 0.05$). L, M, and H are indicator variables for the light, medium, and heavy thinning treatments, respectively.

	Variable	Basal Area (*BA*) Estimate	Basal Area (*BA*) (s.e.)*	Diameter (*QMD*) Estimate	Diameter (*QMD*) (s.e.)*
(β_0)	Intercept	13.3303[n.s.]	(17.5978)	-2.4115	(0.4505)
(β_1)	Pre-treatment Basal Area (BA_{pre})	0.4803	(0.0430)	0.0039	(0.0011)
(β_2)	Pre-treatment Quadratic Mean Diameter (QMD_{pre})	5.3355	(1.1599)	0.9769	(0.0299)
(β_3)	Site Index (*SI*)†	0.8704	(0.1763)	0.0167	(0.0045)
(β_4)	Light thinning (*L*)	-92.1263	(6.2740)	2.1071	(0.1650)
(β_5)	Medium thinning (*M*)	-125.3000	(6.2544)	2.6730	(0.1642)
(β_6)	Heavy thinning (*H*)	-150.0500	(6.2526)	3.4786	(0.1646)
(β_7)	*time*‡	-1.2338[n.s.]	(0.6909)	-0.0104[n.s.]	(0.0226)
(β_8)	$time \times QMD_{pre}$	-0.3710	(0.0299)	-0.0095	(0.0010)
(β_9)	$time \times SI$	0.0748	(0.0072)	0.0026	(0.0002)
(β_{10})	$time \times L$	2.1824	(0.3277)	-0.0170[n.s.]	(0.0107)
(β_{11})	$time \times M$	1.6815	(0.3282)	0.0305	(0.0107)
(β_{12})	$time \times H$	1.1622	(0.3277)	0.0940	(0.0107)

*standard error of parameter estimate
†50-year site index (Farr 1984)
‡years since treatment (i.e., thinning)

(The following steps are perhaps most easily done using an electronic spreadsheet.) Begin by inserting the parameter estimates for **BA** in Table 1 into Equation 1 (e.g., $\beta_1 = 0.4803$). Add the pre-treatment **BA** (275 ft²/ac), pre-treatment **QMD** (6.5 in), and site index (85) where indicated in Equation 1. When **L** = 1, **M** = 0, **H** = 0, and time = 0, Equation 1 predicts a **BA** of 162 ft²/ac immediately post-treatment for the lightly thinned stand; 20 years after thinning (i.e., time

= 20) the lightly thinned stand is predicted to be 260 ft^2/ac. Similarly, if **L** = 0, **M** = 0, **H** = 1, and time = 0, Equation 1 predicts that the heavily thinned stand will have a **BA** of 104 ft^2/ac immediately post-treatment; 20 years after thinning the heavily thinned stand is predicted to be 182 ft^2/ac. In this scenario, average annual **BA** growth during the 20 years post-treatment is predicted to be 25% greater in the lightly thinned stand (4.9 ft^2/ac/yr) than in the heavily thinned stand (3.9 ft^2/ac/yr).

This paper is the first to address the primary objective of the Cooperative Stand-Density Study (CSDS): to understand how young hemlock-spruce stands of different ages and site productivities respond to a range of thinning intensities. The primary reason for this is simply a matter of time. Over a decade was required to establish the study plots (1974-1987). Additionally, if long-term responses to thinning are to be analyzed, decades must pass post-treatment; to analyze 20 years of post-thinning growth response requires that a sufficient number of plots have had 20 or more years pass following treatment. It is sincerely hoped that the CSDS plots—which are now beginning to pay long-term research dividends—continue to be maintained and measured into the future.

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Developing a Unified Monitoring and Reporting System: A Key to Successful Restoration of Mixed-Oak Forests Throughout the Central Hardwood Region

Daniel A. Yaussy, Gregory J. Nowacki, Thomas M. Schuler, Daniel C. Dey, and Eugene J. DeGayner

ABSTRACT

Many national forests and grasslands in the Central Hardwoods region of the United States recently have undergone Land Management Plan revision, which include management areas that promote restoration through a variety of management activities. Monitoring is a vital component of adaptive management whereby the effects from a variety of treatments (including controls) can be analyzed and compared all within a landscape context. A statistically sound and cost-effective opportunity is presented through a unified monitoring effort for national forests spanning the Central Hardwoods region. Statistical power will be gained by increased replications across the landscape and cumulative effects will be addressed more comprehensively. Sharing a common protocol for monitoring activities and a reporting system will enable collective analysis and inference. Challenges will undoubtedly arise in forming a unified monitoring system across multiple forests. The objectives of each forest's management areas and the measures of restoration success need to be similar and reconcilable among the forests. The process of developing and implementing a unified monitoring system must be mutually accepted and financially supported by participating Districts, Forests, Regions, and Research Stations.

An opportunity to efficiently and effectively monitor the ecological restoration of Central Hardwoods region is taking shape. It may be economically beneficial to the Regions and the forests if quick action to take advantage of the "economies of scale" available in designing and collectively implementing a unified monitoring system across forests occurs before each forest commits time, effort and funding to develop their own monitoring system.

Keywords: central Hardwoods, ecosystem restoration, monitoring, surface fires, adaptive management

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INTRODUCTION

Much of the eastern United States was covered by oak-dominated forests (*Quercus sp.*), woodlands, and savannahs prior to Euro-American settlement. Charcoal and pollen records (Delcourt 2002), fire-scars (Guyette and others 2006), and anecdotal accounts from early Euro-American settlers (Whitney 1994) indicate the widespread use of fire by Native Americans to manage habitats. Euro-Americans continued, and possibly increased, burning practices on many of these landscapes (Delcourt 2002, Schuler and McClain 2003) until fire suppression policies were implemented in the 1920s.

Oak-hickory remains the most abundant forest type in the United States, with oak dominated stands that regenerated prior to fire suppression. Because fire was removed as a natural process from these ecosystems, understories readily converted to shade-tolerant, fire-sensitive species such as red and sugar maples (*Acer rubrum, A. saccharum*), beech (*Fagus grandifolia*), and blackgum (*Nyssa sylvatica*) (Abrams 1992, 1998; Schuler 2004). Under these conditions, subsequent timber management that removes overstory canopies, releases these species to dominate the future forest (Abrams and Nowacki 1992). In heavily disturbed areas that are exposed to full sunlight by clearcutting, germinants of shade intolerant species such as yellow-poplar (*Liriodendron tulipifera*) and black cherry (*Prunus serotina*) grow rapidly in height to dominate the regeneration (Brashears and others 2004, Loftis 1990).

In the recent round of Land and Resource Management Plan (forest plan) revisions conducted by the national forests and grasslands in the Eastern and Southern Regions, there has been an increased emphasis on restoring and sustaining oak-dominated ecosystems (Forest Service 2004a-d, 2005a, 2005c, 2006a-e, 2007a-b). Multiple benefits are achieved by maintaining oak-dominated ecosystems through active management, including timber products, wildlife food (mast) and habitat, recreation, and rare plant species (Hutchinson and others 2005, McShea and Healy 2000). A framework for ecosystem restoration established by the National Forest System (Day and others 2006) provides a definition of ecosystem restoration and guiding principles such as a National Strategy and the need for collaboration in attaining these goals. Integration and collaboration within the agency are necessary to maximize limited resources because the magnitude of ecosystem restoration needs greatly exceeds the financial capacity of disparate units of the Forest Service or other resource management organizations. Equally important are external partnerships as ecosystems do not stop at administrative boundaries.

As stated in their forest plans, each national forest (NF) within the Central Hardwoods region will monitor their activities to determine if management actions are achieving the desired future conditions (DFCs). The movement toward these DFCs will be most easily evaluated if they are written with reasonable quantitative metrics as defined in forestry, ecology, and wildlife sciences. Current management activities include: harvesting, prescribed fire, herbicide treatments, and deer abatement techniques. Most monitoring schemes require collection and summarization of data to determine pre- to post-treatment changes and whether advances toward DFCs are truly taking place. Data collected from a single site can be used to explain specific management effects on that specific area. However, credibility is reduced when those results are extrapolated to other sites. For instance, if the Shawnee NF in Illinois finds that frequent, low-intensity fire improves plant biodiversity, it may be sensible to conclude that the same will hold true on the Mark Twain NF (Missouri) or Hoosier NF (Indiana). However, without data from neighboring forests, evidence supporting this claim could be called into question for the Uwharrie NF (North Carolina). As such, the networking of sites allows data comparisons of local vs. regional trends with more confident extrapolation of findings. The National Ecological Classification System (ECS) can be used to stratify the landscape and help guide placement of sites for monitoring. As data accumulate, we are more confident about making claims of positive movement toward DFCs as well as our understanding of what might cause differences in effects. The level of data collection needed to recognize a trend may be more than a single NF would be willing to fund. However, if the intensity of data collection was distributed across several NFs with similar management areas, in similar ECS units, and DFCs, the cost burden would be reduced substantially while maintaining the statistical power of the monitoring. Understanding the differences between sites can be quantified and interpolation of results to new sites is more defensible using an ECS framework.

The need and opportunity exists to establish a coordinated, unified monitoring system for managed oak-dominated stands in eastern forest. However, there are many impediments that must be overcome in the adoption of such a monitoring system. This paper identifies some of these issues.

OBJECTIVES

Several NFs in the Central Hardwoods region have management areas on which they intend to utilize partial harvests and prescribed fire for restoration purposes. In this context, partial harvests are defined as shelterwood harvests and thinning from below, removing the mid-story and leaving the most dominate trees. However, restoration goals and the silvicultural practices used are not necessarily identical among management units or NFs. Typically, forest structure, oak regeneration, and habitat development are listed as objectives of the prescriptions, but these may be given different priorities among the several NFs. For instance, the Wayne NF (Ohio) intends its "Historical Forest" management area to mimic pre-Euro American settlement forests: open woodlands maintained with frequent, low-intensity fires. This forest structure should provide critical habitat for native wildlife species that co-evolved with this vegetation type. Timber production will be a by-product of these management efforts. On the Cherokee NF (Tennessee), restoring historic plant assemblages is the goal of the 9.H management prescription. The intent is to reduce stand density by partial harvesting and manipulate or maintain understory structure. The maintenance will be accomplished using low-intensity fires to create the proper conditions for encouraging oak reproduction and its recruitment into the overstory to provide sustainable woodland, barrens, or savanna ecosystems. The Daniel Boone NF emphasizes animal habitat diversity for prescription area 1.K. It is probable that a single monitoring scheme could be developed that would adequately evaluate the effectiveness of the treatments in attaining the various objectives on the different forests.

The proposed unified monitoring system requires measuring several relevant factors that help detect changes due to management or non-anthropogenic causes including: forest structure and composition, fuel loads, wildlife populations, plant diversity, water quality, and tree regeneration. Knowledge of the stand history, initial vegetation conditions, structure, composition, size distributions, densities, and other overstory and understory features are essential to interpreting the effectiveness of management practices toward achieving the DFC. Standards of factors to be measured will be developed to characterize initial starting conditions. There may be resistance from those in the field that are most knowledgeable about their specific forest conditions. They may feel that their ecosystems differ from other oak-dominated systems enough that a one-size-fits-all approach will not provide them with the information necessary to evaluate the changes specific to their forest. The program design will need flexibility to allow each NF to add local variables if needed without sacrificing the integrity of the regional monitoring scheme. For example: timber rattlesnakes are a species of interest in the state of Ohio. Therefore, if there is a rattlesnake population within their Historical Forest management area, the Wayne NF may wish to add a monitoring program to evaluate the effects of the management practices on the rattlesnake population. However, the addition of local variables requires more intensive sampling to detect changes at that specific site.

PROCESS

Networking and collection

Successful implementation of a unified monitoring program for the NFs in the Central Hardwoods region requires the cooperation and support of District, Forest, and Regional levels of the Forest Service. This endeavor would require a strategic monitoring plan and implementation standards and guidelines developed through collaboration among the Eastern and Southern Regions and the Northern and Southern Research Stations. The Eastern Region's "Courageous Conservation: A sustainable future, a legacy of restoration" strategic framework, promotes this type of collaboration through its mission as a "Partnership Agency" (Forest Service 2005d) and goal of "Protecting ecosystems across boundaries" (Forest Service 2005b).

Responsibilities and funding sources would need to be negotiated and formalized to ensure continued implementation of the program. Key participants will enter and exit positions whose duties include management, data collection, analysis, and reporting. The importance of maintaining the program on each forest will need to be communicated to these participants by their supervisors. Establishment of field data points must be timely, monumented, and fully recorded. Initial training of field data collection crews and continued quality control must be assured. The Forest

Service has an Inventory and Monitoring Institute and the Northern Station has the Northern Monitoring Program, both of which would be able to assist in organizing this unified monitoring program. Accessing the expertise of these groups should prevent "reinventing the wheel" regarding monitoring protocols. Tying into existing multi-organizational networks, such as The Natural Conservancy's Fire Learning Network, also would be advantageous.

Once a baseline of common variables and protocols is implemented, a standard database system would allow for pooling and sharing data and results for local and regional analyses. No network exists within the National Forest System for coordinating the data from different forests. Creating this network would be an ongoing process throughout the span of the restoration projects. Once the data are assembled, researchers will examine the response to treatments across a much broader environmental template. Personnel responsible for regional analysis will be identified in advance and can help to ensure monitoring protocols are followed. Analysis of monitoring data following oak restoration activities increases the feasibility for collaboration among NF and Research Station personnel.

The magnitude of the coordination and cooperation necessary to ensure the successful and continued implementation of a unified monitoring program will probably be the most difficult obstacle to overcome. It could start with a commitment by the Eastern and Southern Regional Foresters and the Station Directors of the Northern and Southern Research Stations and formalized in a memorandum of understanding signed by all parties.

The program would have to provide career and cost reduction benefits to be accepted widely. The monitoring would need to provide evaluations of management activities that are a higher quality and a lower cost than if each NF implemented individual monitoring programs. Scientists would buy into the program if the available data was of the quality and intensity necessary for rigorous statistical analysis. FIA data is used by many scientists for regional analyses. The exact locations of the data collection points are not released to protect the privacy of the cooperating land owners, limiting the ability of researchers to incorporate other georeferenced data into their analyses. Scientists would not have to worry about the limitation on data point locations for the monitoring data collected on NFs.

Adaptive Management

Once a unified monitoring program for the Central Hardwoods region is in place and generating data, individual NFs may have the option of adjusting management prescriptions for adherence to DFCs. DFCs may also need to be altered to fit redefined management objectives especially if the management changes can be quantified and analyzed as extensions to the existing practices. In the process of restoration, there may be one set of management activities used to move from the current state to the DFC, then a shift to a different set of management activities to maintain the DFC. Sustaining the desired state may require periods of variation in activity to allow for regeneration and recruitment of the regeneration into the overstory of the savannah or woodland. There is a possibility that the practices will change drastically enough that the management areas being monitored no longer fit into the monitoring program (e.g. no treatment). The overall monitoring program should not suffer greatly if a few NFs withdrew. The withdrawing NFs would still have a functioning monitoring program, albeit with less statistical power.

CONCLUSION

Many NFs in the Central Hardwoods region have revised forest plans that include management to restore and sustain oak-dominated ecosystems using thinning, regeneration harvests, and frequent, low-intensity prescribed fire. Even though the management practices and DFCs may differ in some aspects, it should be possible to design a unified monitoring program for use by those NFs involved in restoration. Most forests will collect more than this baseline data, but establishing a core set of variables and protocols will provide the ability to pool the data for improved evaluations. It would be a great benefit to all involved if this unified monitoring system could be developed before each forest spent the time and money developing its own stand-alone monitoring systems.

A new network or framework for pooling the monitoring data once it has been collected will increase the accessibility and usefulness to scientists. An integral part of this framework will be the personnel assigned to perform the analysis. The analysis will cover many interrelated components of oak-dominated ecosystems and will require several integrated teams to complete.

The greatest obstacle to implementation of such a program is obtaining the cooperation and support of all the various Forest Service staffs involved. Leadership from the Regional Offices and the Research Stations will be critical. Individual NFs and numerous laboratories within the Stations would have vested interests for participating. Essentially, a coordinated monitoring system applied to several forests in a forest type is a new way of doing business that leverages the assets of each entity. It will make monitoring more affordable and meaningful, research more applicable, management more effective, and increase the Forest Service's public accountability. This coordinated effort can begin with restoration of mixed-oak forests, but the framework and relationships could be used to address many management problems too big for any one entity to handle alone.

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Poster Abstracts

Poster Abstract from the 2007 National Silviculture Workshop

Restoring the Ecosystem With Silviculture and Stewardship Contracting: The Nordic Project

Christopher E. Casey and Joseph Torres

ABSTRACT

As a first step in implementing the Green Mountain National Forest's new Land and Resource Management Plan, the Nordic Project is located on the Manchester Ranger District in the Towns of Peru, Winhall, and Landgrove in Bennington County, and in the Town of Londonderry in Windham County. It consists of 2,236 acres featuring silvicultural treatments in support of ecosystem restoration involving regeneration of uncommon species such as aspen and oak, creation of permanent upland openings, conversion of non-native softwood plantations to restore native species, improvements to deer wintering habitat, restoration of aquatic habitat and riparian zones, production of high quality sawtimber and other forest products. Also included is designation of cross country ski trails, scenic vistas, trail relocation and identification and preservation of historic archeological sites. Fourteen timber sales with multi-resource treatments total about 9.5 Million board feet or 15,000 CCF of hardwood and softwood sawtimber and pulpwood. Twelve will be implemented using Stewardship Contracts. It is significant because up front planning and collaboration with citizens, partners and town governments created broad support resulting in no appeals or litigation when regarding it is the largest and most complex project on the forest in memory.

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Poster Abstract from the 2007 National Silviculture Workshop

Variation in Microclimate Associated With Structural Retention Harvests in the Pacific Northwest

Troy D. Heithecker and Charles B. Halpern

ABSTRACT

Green-tree or structural retention is becoming increasingly common as a method of regeneration harvest in the Pacific Northwest. Amelioration of microclimatic stress is assumed to be one mechanism by which overstory retention enhances the survival of forest organisms and the potential for ecosystem recovery following timber harvest. We examined patterns of transmitted light (photosynthetic photon flux density, PPFD), air and soil temperature, and soil moisture in a large-scale green-tree retention experiment in mature, coniferous forests at three locations in western Washington. To quantify the effect of varying levels of retention, we compared daily growing season microclimate and residual forest structure in dispersed retention harvest units representing 0, 15, 40, and 100% of original basal area. Additionally, we quantified spatial gradients in microclimate inside 1-ha forest aggregates, effects of aspect on these gradients, and how microclimatic conditions compared to adjacent harvest areas and larger tracts of undisturbed forest (controls).

Level of retention had a significant and predictable effect on microclimate: PPFD and mean and maximum air and soil temperatures decreased with increasing level of retention. PPFD showed the strongest response, but did not differ between 40 and 100% retention. Mean and maximum air temperatures were significantly greater at 0 and 15% retention than at 100%. In combination, topography, residual forest structure, and understory variables were good predictors of PPFD and mean and maximum temperatures (R^2 of 0.55-0.85 in multiple regression models), but were poorer predictors of minimum temperatures and soil moisture (R^2 of 0.10-0.51).

Inside 1-ha aggregates, trends in light and temperature were generally similar; values were greatest at the edge, but declined sharply inside the aggregate, with most change occurring within 15 m of the edge. Beyond this distance, light generally declined to levels observed in the controls. Soil temperatures exhibited greater spatial variation and stabilized further from the edge (10-30 m), but air temperatures were generally higher than those in controls. Aspect exerted strong effects on light and temperature, particularly within 15 m of the edge, as did forest structure. Where tree density was low, elevated temperatures penetrated further into the aggregates and aspect-related differences were small.

Our results suggest that when applied in a dispersed pattern, 15% retention, the current minimum standard on federal forests within the range of the northern spotted owl, does little to ameliorate microclimatic conditions relative to traditional clearcut logging. Conversely, our results suggest that 1-ha aggregates are sufficiently large to support areas in which microclimate is comparable to undisturbed forest and suitable, in the short-term, for persistence of forest-dependent species.

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Poster Abstract from the 2007 National Silviculture Workshop

Pruning Western White Pine to Reduce White Pine Blister Rust

Holly Kearns, John Schwandt, Brennan Ferguson, and Chris Schnepf

ABSTRACT

White pine blister rust (WPBR) is an exotic rust fungus that has caused dramatic changes in forested ecosystems throughout the West. Cronartium ribicola, the causal agent, was imported in 1910 to British Columbia on infected nursery stock from France. All nine native North American species of white pines (five-needled pines) are highly susceptible. WPBR has spread throughout the range of most of these species, which includes some of Western North America's most ecologically and economically important forest ecosystems.

Infection of white pines can only occur by spores produced on an alternate host (usually gooseberries or currants – Ribes spp.). Under very moist conditions, these spores land on the needles, germinate, and enter the host through the stomata. The fungus then grows within the vascular tissues into the bark, growing down the branch toward the main stem. This creates an expanding canker that girdles the branch. As the branch beyond the canker is killed, a distinctive red "flag" is created. When the fungus reaches the stem, it girdles the stem resulting in top kill or tree mortality.

WPBR infects white pines only through green needles during prolonged periods of high humidity. Green branches close to the ground are at highest risk of infection because environmental conditions are favorable for the rust (i.e. shady, cool, and moist). Young trees are especially vulnerable because blister rust infections can reach the stem and girdle small diameter trees very quickly.

Pruning takes advantage of the fact that WPBR is an obligate parasite; the fungus requires a living host and cannot survive on dead plant material. Pruning lower branches not only removes infections before they reach the stem, but also removes the lower needles as infection sites. In studies by the U.S. Forest Service in northern Idaho, pruning the lower 8 – 10 feet of 20-foot tall, 15-year-old, naturally regenerated white pine decreased mortality by nearly 50 percent over the next 35 years compared with unpruned white pines.

Breeding programs to improve the level of WPBR resistance were initiated in the 1950s after individual uninfected white pines were observed in severely infected stands. This improved stock is outperforming natural white pine regeneration but is not immune to WPBR. While pruning does not change the level of genetic resistance in a tree, it can help maintain white pine as a functioning component in mixed forests. This is especially important in mixed conifer stands due to white pine's high tolerance to native root diseases, which are seriously impacting the Douglas-fir and true firs now dominating lands historically dominated by western white pine.

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Pruning can provide many benefits including: improved survival, improved numbers of infection-free trees, preventing stand transition to less desirable species, protecting investment in western white pine stock with genetically improved resistance, and production of higher quality, clear wood. Pruning should be performed when WPBR infection levels threaten management objectives, and typically, only those trees desired as crop trees are pruned. We recommend that pruning be delayed until white pines are old enough (greater than 10 years) to have been exposed to WPBR and be exhibiting symptoms of infections, and the average height of white pines is at least 16 feet to allow the lower 8 feet to be pruned while maintaining at least 50% live crown. All branches (live and dead, infected or not) should be pruned from the bottom 8 feet of the stem, but never prune more than 50% of the live crown. White pines with stem cankers should also not be pruned; these trees cannot be "helped" by pruning. In addition, only trees with branch cankers at least 4 inches from the main stem should be pruned. WPBR cankers less than 4 inches from the stem may already have fungal tissue in the stem and may be considered "lethal."

Poster Abstract from the 2007 National Silviculture Workshop

Precommercial Thinning in Southeast Alaska and Its Impact on Wood Quality

Eini C. Lowell, Robert A. Monserud, and Alexander Clark III

ABSTRACT

Since the 1900's, about 400,000 acres of timber on Forest Service land and an equal amount on other ownerships in southeast Alaska have been harvested and successfully naturally regenerated. Among several management themes that have been developed for young-growth stands are those that are designed to create stand structures that are beneficial to wildlife, enhance riparian zones, and produce sustainable timber resources. These themes often include the need for pre-commercial thinning (PCT) to accomplish the desired stand features. It is important to understand the effect of such management activities on the quality of wood fiber that may later be removed from these stands and how that quality impacts product opportunities and associated economic potential. The general response of trees to thinning is slower crown recession, increased branch diameter, increased taper and reduced wood specific gravity. This project establishes baseline product recovery information about the volume and quality of lumber products manufactured from young-growth western hemlock (*Tsuga heterophylla* (Raf.) Sarg) and Sitka spruce (*Picea sitchensis* (Bong.) Carr.) from even-aged stands in southeast Alaska. Wood quality is addressed from several perspectives: visual lumber grades, mechanical properties, and anatomical features. The study compares the quality differences between stands that have been pre-commercially thinned and those not thinned, and determines if spacing at time of pre-commercial thinning influences product volume, quality, and value.

Nine young-growth stands that were thinned approximately 20 years ago were identified by Forest Service personnel at the Craig, Thorne Bay, and Petersburg Ranger Districts on the Tongass National Forest. Eight of the sites were located on Prince of Wales Island and the ninth on Mitkof Island. Two sites were on State of Alaska Department of Natural Resources (DNR) land. All stands contained a known precommercial thinning treatment and an adjacent no-treatment control stand .To facilitate the removal of a relatively small number of trees, sites were accessible from existing roads and on terrain where locally available harvesting systems could operate efficiently. Sites were selected to represent as wide a range as possible of stand ages and site classes for both thinned and unthinned stands. Thinning spacings ranged from 10 x 10 ft to 25 x 25 ft.

The study is designed using paired-plots (treatment vs. control) on a series of stands with different levels of treatment (thinning to a specified regular spacing). The sample was stratified by 4-in breast height diameter (dbh) classes with three trees in each class for a total of fifteen trees/species/treatment/site. Because not all dbh classes were present, a total of 461 trees were selected. The range and average dbh of harvested trees were:

	Hemlock		Spruce	
	Control	Thinned	Control	Thinned
no. trees	97	110	127	127
dbh range	9.5" – 24.6"	10.0" – 31.2"	9.5" – 28.2"	10.0" – 32.3"
avg. dbh	14.0"	14.5"	14.2"	16.3"

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During tree selection, it was observed that target spacing and actual spacing at the time of conducting this project appeared to differ. Stand exams were conducted to determine actual spacing at time of sampling.

Trees were harvested and long logs transported to the Ketchikan Wood Technology Center in Ketchikan, Alaska. Woods length logs were graded and scaled (both cubic and Scribner) by the Pacific Rim Scaling Bureau, bucked into mill length logs, and re-scaled. A disk was cut from the large end of the butt log and from the end of every subsequent short log. Radial strips _ x _ inches square were cut from bark to bark through the pith of each disk, dried, glued to core holders and sawn into 2 mm thick strips. Annual ring growth, ring specific gravity and proportion of latewood were determined for each radial strip using a scanning x-ray densitometer. Logs were sawn into dimension lumber (2 x 4 in and 2 x 6 in) using a portable sawmill. The lumber was kiln dried, planed, and graded according to National Lumber Standard Grading Rules. Grade controlling defect for each piece of lumber was also recorded. Every piece of lumber was non-destructively tested (transverse vibration according to ASTM standard D6874, 2003) for Modulus of Elasticity (MOE). A 20 pct stratified random sub-sample of trees was selected for further testing of mechanical properties. All lumber from these trees was destructively tested (static bending of full size lumber according to ASTM standard D6874, 2003) to determine modulus of elasticity (MOE) or stiffness and modulus of rupture (MOR) or strength. Complete tracking of each piece of lumber allows for reconstruction of recoverable volume and value from individual logs and trees.

The hemlock and spruce trees growing on the thinned plots responded positively to the thinning treatments. Thinning reduced the over crowding and there was sufficient moisture and nutrients to maintain wood quality. Thus, spruce and hemlock stands on the Tongass National Forest could be pre-commercial thinned to improve wildlife habitat, and enhance riparian zones with no negative impacts on sustainable timber resources.

Poster Abstract from the 2007 National Silviculture Workshop

3P Remote Sensing (3PRS): An Efficient Way to Estimate Stand Volume in Low Value/Biomass Timber

Matt Oberle, Dave Johns, Ken Cormier, Gary Boyack, and Andrew Sánchez Meador

ABSTRACT

3P Remote Sensing (3PRS), a two-stage sampling method using large-scale aerial photography and traditional 3P (probability proportional to prediction) sampling techniques may be an efficient and cost-effective way to estimate the quantity of low value timber products. The first stage estimates relative volume per acre for each sample plot based on visual clues from aerial photos. Estimates are on a normalized scale from 0 to 100, called the RVI (Relative Volume Index), where 0 is no volume and 100 is the highest volume in the population. In the second stage, a subset of the first stage sample plots is chosen for field measurement using 3P selection. Plot centers for each measured plot are located on the ground, a fixed area plot is established and every tree to be harvested on the fixed plot is measured. Predicted to measured volume ratios are then calculated and used to adjust the total estimates.

Tools and technology used for this process, such as stereo photos, large-scale ortho-photography and computer software are normally available to forestry units. While the 3PRS method can provide an estimate of total biomass volume and a measure of sampling error, it is not able to accurately furnish other information such as individual tree characteristics and thus is not suited for all cases. The 3PRS method requires a uniform silvicultural prescription, a single value for the timber product, a familiarity with the timber's volume variability via a walkthrough or guidance from a local forester, consistent volume (RVI) estimates and good ground truthing during the second stage for the measured / predicted ratio.

Further testing of this method will be conducted in the Estes Valley Stewardship / Service Contract Pilot Project on the Arapaho-Roosevelt National Forest starting in 2007.

Overall, 3PRS may serve as a cost effective tool for estimating the quantity of low-value biomass timber.

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Poster Abstract from the 2007 National Silviculture Workshop

Fiber, Feathers and Friends–An Integrated Approach to Managing Jack Pine to Benefit Kirtland's Warbler, Maintain Yields and Involve Partners

Kirk Piehler and Jean Perkins

ABSTRACT

Jack pine (*Pinus banksiana*) is a common fiber producing tree in the Great Lakes states. Dense stands of young jack pine provide optimal nesting habitat for Kirtland's warbler (*Dendroica kirtlandii*) or "KW", a federally listed species. The species breeding range is primarily Michigan's northern Lower and eastern Upper Peninsulas. The Hiawatha National Forest's 2006 Forest Plan contains management direction, including goals for average annual acres of jack pine regeneration, designed to promote recovery of KW. On the Hiawatha National Forest (HNF), located in the eastern Upper Peninsula, young jack pine stands about 6-16 years of age (about 5-15 feet tall) are considered suitable for nesting. Jack pine is adapted to well drained and sandy soils (i.e. "barrens"), conditions that have been present since the retreat of the Wisconsin ice sheet about 14,000 years ago. Historically, vegetation on the jack pine barrens was maintained by natural wildfires that occurred frequently throughout the region. With the arrival of wildfire suppression, an emphasis on forest management practices to regenerate jack pine is required for the continued recovery and viability of the Kirtland's warbler.

Habitat standards suggest that jack pine stands less than 80 acres in size are seldom occupied. The highest potential for nesting will occur in stands or complexes greater than 1000 acres with an average stocking density of about 1,100 trees per acre or more, including small non-forest inclusions (approximately 25 percent open area per acre), or approximately 5'x 6' spacing or less. Due to the open-land requirement, the actual tree density would be about 1,450 trees per acre in habitat outside of the open areas. Natural regeneration or planting can be used to regenerate jack pine for KW on the HNF.

Reforestation of jack pine for KW on the HNF emphasizes natural regeneration, which is less expensive than full planting. Site preparation consists of crisscross passes with a rollerchopper to crush jack pine slash remaining after a mature jack pine stand has been clearcut. Spiked anchor chains dragged behind the rollerchopper scarify the soil at the same time. Jack pine is extremely intolerant of shade, and cones are serotinous. Rollerchopping brings the cones on the slash close enough to the ground that radiant heat from the sun will open them. Site preparation takes place as soon as possible after harvest so seed viability will be at maximum, and so the soil will be scarified before the jack pine cones open (generally in July following harvest), so that seeds falling from cones in the logging slash germinate on mineral soil. Natural regeneration must sometimes be supplemented with additional seeding or planting to reach the stocking density needed to meet KW nesting requirements. Stocking density must also be kept below densities that might reduce later marketability. After stands grow out of the size that provides KW nesting habitat, they are managed conventionally for fiber production.

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Partnerships appear to be a promising means for funding KW habitat work if either full or supplemental planting of jack pine for KW is prescribed. The Hiawatha National Forest was the only Forest in Region 9 to receive a grant from the National Arbor Day Foundation in 2006. This grant is being used in the spring of 2007 to create and/or restore habitat for Kirtland's warbler through supplemental planting in areas where natural regeneration of jack pine alone did not result in sufficiently dense stocking to meet KW habitat needs. Stewardship contracting is another emerging tool that may be used to facilitate KW habitat creation or restoration.

Poster Abstract from the 2007 National Silviculture Workshop

Throughfall Monitoring of Old Growth, Second Growth, and Cleared Vegetation Plots on Prince of Wales Island, Alaska

Katherine M. Prussian

ABSTRACT

The density of forest canopy affects the amount of rain reaching the forest floor in forested environments of Southeast Alaska. Automated tipping bucket rain gages were used to monitor throughfall in Old Growth (OG), Second Growth (SG), and Cleared (CC) vegetation sites on Prince of Wales Island, Alaska, as an indicator of varying forest conditions. Data collected during 2004 and 2005 included 24 storms ranging from 0.4 to 7 inches of gross rainfall. Data following 2006 included 11 storms ranging from .3 to 2.2 inches of gross rainfall. This monitoring is an effort to determine the affect, if any, that forest management could have on throughfall, and furthermore, lend information to forest management effects on the water balance within a watershed. These results suggest that gross rainfall in cleared vegetation sites is greater than throughfall occurring in both old growth and second growth stands. Further, interception by a dense second growth canopy accounted for an average of 35% at Site A, and 65% at Site B, of the gross precipitation. Interception of an old growth canopy accounted for an average 51% at Site A, and 42% at Site B of the gross rainfall. Similar results were found in an earlier study by J.H. Patric where interception accounted for 25% of the gross annual precipitation in a forested areas near Juneau, Alaska (Patric, J.H., 1966). Further rainfall monitoring, and additional site sampling, will provide greater detail relative to canopy density, elevation, aspect, antecedent conditions, and storm intensity.

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Poster Abstract from the 2007 National Silviculture Workshop

Direct Seeding of Jack Pine on the Hiawatha National Forest

Al Saberniak and Paul Berrang

ABSTRACT

The recent discovery of the federally listed endangered Kirtland's warbler (*Dendroica kirtlandii*) on the Hiawatha National Forest (NF) in Michigan's Upper Peninsula has increased interest in regenerating dense stands of jack pine (*Pinus banksiana* Lamb.) on outwash sands. The Hiawatha NF has frequently used direct seeding of jack pine to augment natural regeneration on these sites, but we don't know if this is effective or even necessary.

Direct seeding of jack pine has been very effective when the seed is applied directly to bare mineral soil after the site had been burned and deeply scarified with an Athens disk. The Hiawatha NF uses a less intensive site preparation and applies the seed on top of the snow in late spring. We wanted to evaluate the effectiveness of direct seeding under these conditions.

Six stands were selected that had been cut in either 2001 or 2002 with the intention of regenerating jack pine. The number of trees left uncut varied considerably among stands. Each stand was prepared for seeding by double rollerchopping and chaining in 2003. Either 20 or 30 plot centers were established along transects in each stand at places where site preparation was judged to be adequate. Each plot was randomly assigned to either the seeded or non-seeded treatment with a coin toss. The number of cones on the ground at each plot was qualitatively estimated. The residual overstory around each plot was measured as well. Seed was applied at the rate of 4 oz/ac to the appropriate plots in spring of 2004 with a seeder attached to the back of a snowmobile. A 250th ac circular plot was established around each plot center and with the help of numerous employees of the Hiawatha NF, the number of pine seedlings was counted in 2004, 2005, and 2006. Seedlings were assumed to be jack pine unless they could be otherwise identified.

Full stocking would be the equivalent of either 3 or 4 seedlings/ac of acceptable growing stock depending on whether the site was being regenerated for Kirtland's warbler habitat or for other objectives. Across all six stands in 2006 there was an average of 10 seedlings per unseeded plot and 17 seedlings per seeded plot, a statistically significant difference. Increasing the number of seedlings on plots that are already overstocked only makes sense if large numbers of seedlings are expected to die. We do expect many of the smaller seedlings to die, but not enough to decrease stocking below target levels.

We compared seeded and unseeded plots at each of the six sites (Table 1). In 2006 seeding increased the number of seedlings at two of the six stands. The difference in the effectiveness of direct seeding among stands appeared to be related to the cone crop. Plots that had a low number of cones on the ground at the time of seeding had only a third as many seedlings as plots that had a high number of cones. Foresters may be able to predict the need for seeding by evaluating the cone crop.

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Some plots had regeneration of red pine (*Pinus resinosa* Ait.) as well as jack pine. This was related to the residual red pine overstory, plots with red pine basal area had four times as many red pine seedlings as plots without red pine basal area. While a mixture of red and jack pine is compatible with some management objectives it is not desirable for Kirtland's warbler habitat.

Table 1 – Average number of live jack pine seedlings per 250th acre plot three growing seasons after half the plots were seeded. Pairs of numbers in the same row followed by the same letter are not significantly different (P < 0.05).

District name	Stand/ compartment	Number Live Jack Pine Seedlings per Plot	
		Seeded	Not seeded
Munising	81/7	23 a	25 a
Munising	81/19	14 a	11 a
Sault Ste. Marie	23/2	16 a	7 b
Sault Ste. Marie	23/16	10 a	4 a
Sault Ste. Marie	24/32	10 a	7 a
Sault Ste. Marie	24/34	25 a	12 b

Poster Abstract from the 2007 National Silviculture Workshop

Spruce Aphid Infestation of Sitka Spruce in Southeast Alaska

Mark Schultz, Dustin Wittwer, Paul Hennon, Melinda Lamb, Andris Eglitis, Nellie Olsen, Ann Lynch, Chris Fettig, Robert Borys, Chris Dabney, Roger Burnside, and Neil Kidd

ABSTRACT

The Problem

(Andris Eglitis)

Sitka spruce (*Picea sitchensis* (Bong.) Carr.), historically has been subjected to attack by the spruce aphid, ***Elatobium abietinum*** (Walker) (***Homoptera: Aphididae***). Spruce aphid can cause severe needle drop and death of the tree after several defoliation events. Spruce aphid outbreaks are usually preceded by mild winters, and normally last for a short time, perhaps two or three years. Since 1975 the outbreak has been more or less continuous. Aphid damage may become apparent in March or April before the new spruce growth begins. Populations continue to increase until early summer, when sap nutrition decreases. By midsummer the populations may reach a low point because reproduction rate drops with decreased nutrition, migration by winged females, and increased parasitism. In the fall, the aphids may increase in number and infest the current year needles. This second peak in September and October is usually not as damaging as the spring population, but significant defoliation may still occur if the autumn is a mild one.

Distribution

(Dustin Wittwer, Paul Hennon, and Nellie Olsen)

Aspect and maritime influence at the beach fringe have a great deal to do with spruce aphid survival. Southern aspects that are sheltered and near the western edge of the archipelago of southeast Alaska islands are many degrees warmer than elsewhere. Warmer temperatures, by5-10 °C, occurred as much or more than two weeks longer in the fall and two weeks sooner in the spring in Sitka and Craig than in Juneau, AK.

Climate Change

(Ann Lynch)

Since 1940, mean annual midpoint temperatures (the midpoint is halfway between the minimum and maximum temperatures) at Sitka, AK increased 2.0°C. The minimum winter temperature has increased by 6°C. The number of winter days with below-freezing temperatures has decreased by 20 days. The date of the last spring frost has retreated 15 to 20 days in Sitka.

Chemical Control

(Chris Fettig, Roger Burnside, Robert Borys, Chris Dabney, Melinda Lamb)

The application of Acecaps significantly reduced the density of aphids on Sitka spruce by 92.4% (June 2005) and 100% (September 2006). No other significant differences were observed among treatment (Kioritz or Arborjet) means during these two sample periods. Acecaps were the most effective means of control but during most evaluations relatively few aphids were encountered overall.

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Vertical and horizontal digital photographs were taken in April and September 2005 and 2006 to compare the changes in needle density on treated and untreated trees. Using the HemiView software, developed by Delta-T Devices, control trees lost on the average one and one-half percent of their needle cover each in 2005 and 2006 and, this includes the gain in needle cover by new growth after leaf-out in June.   The Acecap treated trees had an average gain in needle cover of two percent.

Future Monitoring

(R. Burnside)

Little is know about where spruce aphid resides during the summer hiatus and during cold periods or much about how populations recover in the spring. Using fluorescent dyes and netted branches and trees we hope to determine some site specific information about spruce aphid biology.

Climate Modeling

(Neil Kidd and A. Lynch)

Winter snowfall and low winter temperature account for over half of the variability in the spruce aphid outbreak frequency.

English equivalents

When you know:	Multiply by:	To find:
Millimeters (mm)	0.0394	Inches
Centimeters (cm)	0.394	Inches
Meters (m)	3.28	Feet
Kilometers per hour (km/hr)	0.621	Miles per hour
Hectares (ha)	2.47	Acres
Kilograms (kg)	0.0011	Tons
Megagrams per hectare (Mg/ha)	0.446	Tons per acre
Gram-force per square centimeter (g/cm^2)	0.014	Pounds per square inch
Kilograms per cubic meter (kg/m^3)	0.0624	Pounds per cubic foot
Square meters per hectare (m^2/ha)	4.37	Square feet per acre