FINAL REPORT, JOINT FIRE SCIENCE PROGRAM PROJECT 01B-3-3-15

Title: Integrating prescribed fire into management of mixed-oak forests of the mid-Atlantic region: Developing basic fire behavior and fuels information for the SILVAH system.

Location: Numerous locations on federal, state, private, and tribal lands in Connecticut, New Jersey, Pennsylvania, and West Virginia.

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PURPOSE OF THE PROJECT

There is growing interest in using more prescribed fire to sustain mixed-oak forests throughout the eastern United States. But, prescribed fire is still in its infancy in this forest type. Consequently, there are many knowledge gaps in basic fire science. Managers desiring to begin using fire or use more fire are hesitant to do so because of these gaps. This study seeks to answer two basic fire questions.

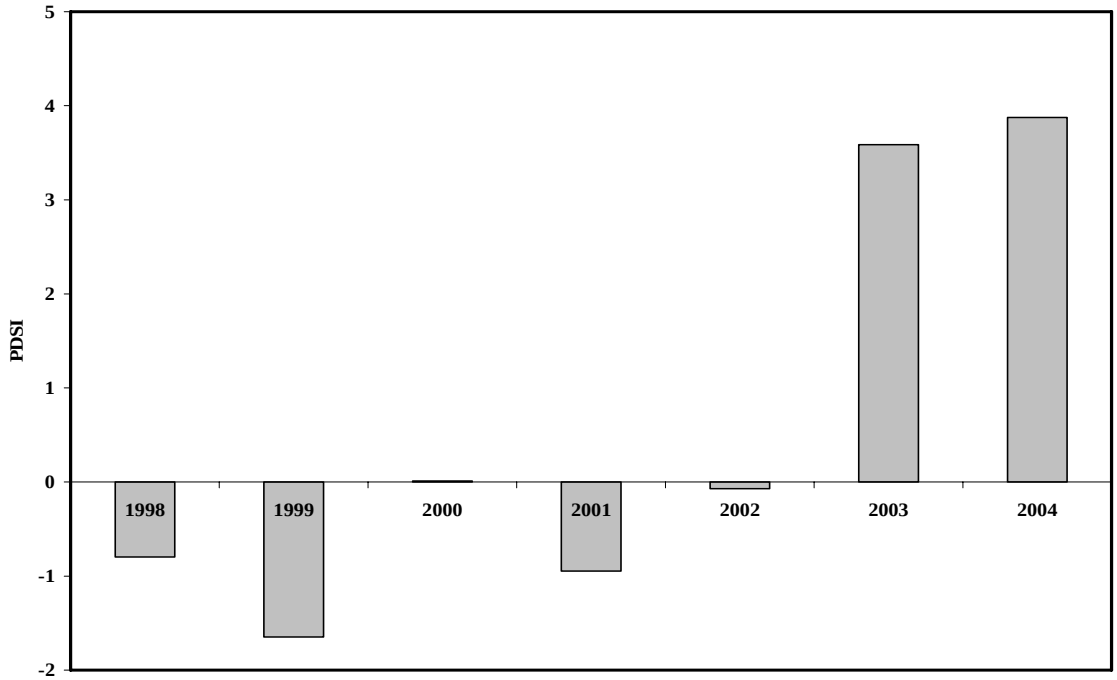
1. Which of the 13 Anderson fuel models accurately depict common understory conditions in oak forests?
2. What proportion of the advance regeneration will sprout after burning?

HISTORY OF THE PROJECT

This project was submitted to the Joint Fire Science Program for funding consideration in late 2001. The project was approved in early 2002 with an anticipated ending date of December 2004. From that point on, this project encountered considerable difficulty. For unknown reasons, there was a time lag of several months between project approval by the Governing Board and the funding becoming available at the project level. This caused a delay in the start of the study and, consequently, several opportunities were missed to collect data from prescribed fires conducted during the spring 2002 fire season. In August 2002 the Forestry Sciences Laboratory at Irvine, PA (duty station for PI Brose) was heavily damaged by an arson fire (Figure 1). Personnel and resources were diverted to the rebuilding effort and all opportunities to study prescribed fires during the fall 2002 fire season were lost. Also in fall 2002, the 5-year period of normal to below normal precipitation that had covered much of the mid-Atlantic region and southern New England ended. In its place came a 2-year period of above normal precipitation (Figure 2). In 2003, Pennsylvania had its 4th wettest year ever; 2004 was the wettest ever. The excessive rainfall made it nearly impossible to do any prescribed burning and many burns were delayed one or more years (Table 1). In spring 2003, Doug Riley, the FMO at the

Figure 1. The Forestry Sciences Lab at Irvine, PA shortly after an arson fire on August 10, 2002. The facility was heavily damaged as evidenced by the scorched trees in the background.

Figure 2. Graph of the Palmer Drought Severity Index for northern Pennsylvania from 1999 to 2004 inclusive. Note the dramatic change in drought conditions from 2002 to 2003 as the weather became much cooler and wetter.



Delaware Water Gap NRA, retired suddenly due to family health reasons. The loss of this key cooperator meant that the prescribed fires planned for the Delaware Water Gap NRA had to be postponed until a new FMO arrived. That occurred in early 2004. What all these delays and problems did was effectively ruin the first two years of the project. A 1-year extension was sought and obtained in fall 2004 to prolong the project until December 2005. By that time, some but not all, the planned prescribed fires had occurred.

Table 1. The New Jersey and Pennsylvania prescribed fires that were part of this study. Those in bold were delayed a year or more due to uncooperative weather. Similar delays were experienced in Connecticut and West Virginia. Abbreviations are NH – northern hardwood, Evrg – evergreen, and Dcds – deciduous.

Rx Burn	**Fuel Type**	**Sample Size**	**Intended Date**	**Actual Date**
St Maple 1	NH litter	2	Spring 2002	Spring 2002
Edeburn 1	Evrg shrub	3	Spring 2003	Spring 2003
Firetower 1a	Dcds shrub	3	Spring 2003	Spring 2003
Firetower 1b	Oak litter	3	Spring 2003	Spring 2003
Edeburn 2	Dcds shrub	4	Fall 2004	Fall 2004
BML 1a	Oak litter	3	Fall 2004	Fall 2004
BML 1b	Dcds shrub	3	Fall 2004	Fall 2004
Keller Road	**NH litter**	**3**	**Spring 2003**	**Spring 2005**
Kinzua Hts	**Oak litter**	**4**	**Spring 2003**	**Spring 2005**
Rimrock	**Oak litter**	**3**	**Spring 2003**	**Spring 2005**
337 Road	**Oak litter`**	**4**	**Spring 2003**	**Spring 2005**
NC Trail	**Oak litter**	**3**	**Spring 2003**	**Spring 2005**
Callen Run	**NH litter**	**3**	**Spring 2004**	**Spring 2005**
Radiotwr 1	Slash	3	Spring 2005	Spring 2005
Pocono	**Dcds shrub**	**4**	**Fall 2003**	**Fall 2005**
Oil Road 1a	**Oak litter**	**6**	**Spring 2004**	**Spring 2006**
Oil Road 1b	**NH litter**	**3**	**Spring 2004**	**Spring 2006**
Firetower 2	**Oak litter**	**4**	**Spring 2004**	**Spring 2006**
Radiotwr 1a	Slash	5	Spring 2006	Spring 2006
Radiotwr 1b	Oak litter	3	Spring 2006	Spring 2006
Oil Lease 2	NH litter	4	Fall 2006	
Kepler Rd.	**Evrg Shrub**	**3**	**Spring 2003**	
Kepler Rd.	**Slash**	**3**	**Spring 2003**	
Lonestar 1	**Dcds shrub**	**3**	**Fall 2004**	
Lonestar 2	**Evrg shrub**	**3**	**Fall 2004**	
St Maple 2	**NH litter**	**4**	**Spring 2003**	
BML 2a	**Oak litter**	**3**	**Fall 2005**	
BML 2b	**Dcds shrub**	**3**	**Fall 2005**	
BML 2c	**Evrg Shrub**	**3**	**Fall 2005**	

MAJOR FINDINGS

The findings reported here should be viewed as interim as there is still much work in progress on this project.

Evaluation of fuel models

The understory fuels encountered in this study can be organized into five groups based on the average maximum temperature recorded during the prescribed burns. They are:

1) northern hardwood leaf litter – 104 °C
2) oak leaf litter – 192 °C
3) deciduous heath (ericaceous) shrubs – 285 °C
4) evergreen heath shrubs – 506 °C
5) logging slash – 782 °C.

Preliminary comparisons of BEHAVE-generated fire behavior predictions of these fuel types to field measurements of monitored prescribed fires indicate that the Anderson fuel models are appropriate in some situations but not others (Table 2).

Fire behavior in northern hardwood leaf litter is accurately portrayed by Fuel Model 08 but is underestimated in oak leaf litter. Conversely, fire behavior in oak leaf litter is well represented by Fuel Model 09 (loose leaf litter) but is overestimated in northern hardwood leaf litter. These findings are consistent regardless of fire seasonality and are likely the result of several inherent differences in the two forest types. Oak leaves weigh more and and burn hotter than leaves of most other hardwoods. Also, oak leaves form a porous fuel bed and are slow to decompose even after being buried in snow for several months. Leaves of most other hardwoods form a flat mat after being compressed by snow and decay quite rapidly.

Table 2. Preliminary evaluation of the fuel types encountered in this study and their appropriate fuel model, if any. The f and s superscripts denote fall and spring fire seasons.

Fuel Type	Sample Size	Flame length	Rate-of-spread	Fuel Model
No. hdwd litter	11	< 1 ft	1 – 2 chains/hr	8
Oak litter	33	2 – 4 ft	7 – 10 chains/hr	9
Deciduous shrub^{f}	11	3 – 5 ft	8 – 12 chains/hr	9
Deciduous shrub^{s}	9	4 – 7 ft	15 – 20 chains/hr	6
Evergreen shrub	8	6 – 12 ft	10 – 35 chains/hr	?
Logging slash	15	10 – 15 ft	4 – 8 chains/hr	12

Fire behavior in deciduous heath shrubs (blueberry, deerberry, huckleberry, etc) is influenced by seasonality. In the fall after these shrubs are dormant, fire behavior is slightly more intense than that predicted by Fuel Model 09. This is perhaps due to the

small stature of the shrubs, usually less than 2 feet tall, holding many of the recently fallen leaves up off of the ground. This creates a porous, well aerated litter layer that burns somewhat hotter than an ordinary litter layer. During and shortly after leaf expansion in the spring, fire behavior in deciduous heath shrubs can be surprisingly intense. Many of these shrub species have resin droplets on their foliage and branch tips and it appears that these droplets contribute considerably to increasing fire behavior beyond what one would initially expect. At this time, Fuel Model 06 appears to be a good match for this fuel type.

Fuel Model 06 is recommended for depicting hardwood slash. That may not be correct. Preliminary results from this study indicate that hardwood slash burns considerably hotter than BEHAVE-generated fire behavior predictions for this fuel model. One of the slash fuel models, possibly FM 12, may be more appropriate to use in hardwood clearcuts. However, there was considerable variability in the data and the sample size was small so caution must be exercised in applying this finding. A mitigating factor appears to be the presence of large numbers of black birch (*Betula lenta*) regeneration and saplings amongst the slash. This species produces several aromatic compounds that become flammable if sufficiently heated.

The evergreen heath shrubs (mountain laurel and rhododendron) do not appear to be represented by any of the 13 fuel models. Their ignition is unpredictable. If they do not ignite, a surface fire behaves like a leaf litter fire. If they do catch fire, the fire can move incredibly fast and produce tremendous flame lengths. This explosiveness also made them difficult to study as cooperating agencies were often reluctant to prescribe burn areas containing thickets of evergreen heath shrubs.

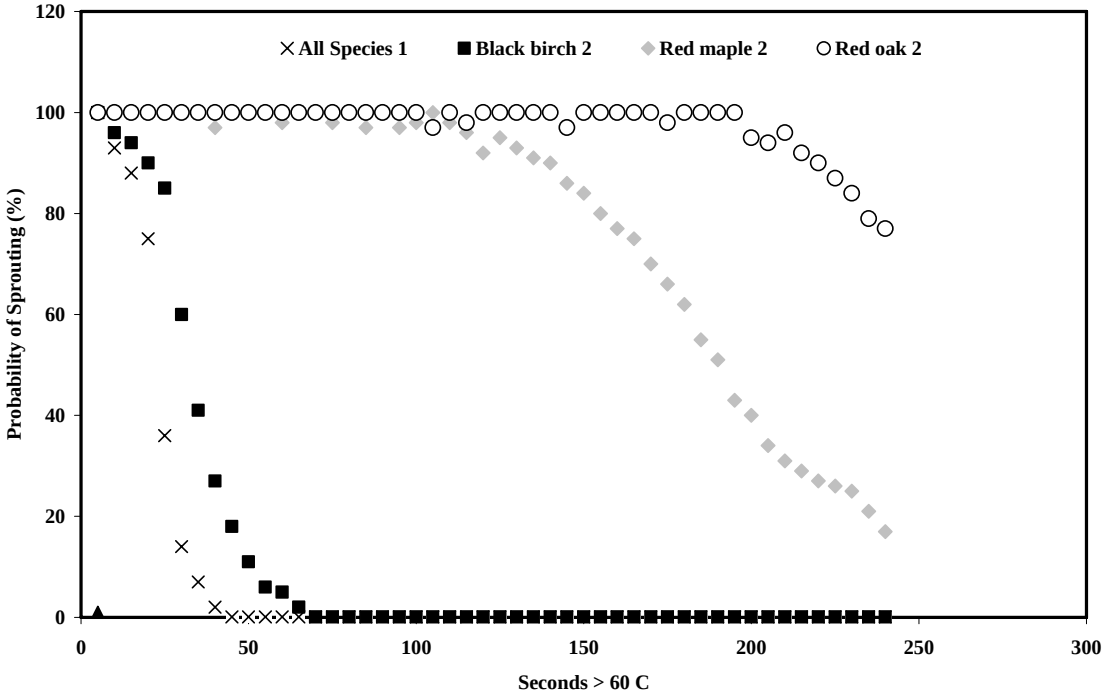
Sprouting probabilities of hardwood regeneration

The sprouting ability of hardwood regeneration is a function of several factors. They are: 1) root collar diameter of the stem, 2) root collar location in the forest floor, 3) season of the fire, 4) number of seconds the fire exceeds 60 °C, and 5) maximum fire temperature. The first two factors are largely species specific; some emphasize root development, i.e., the oaks, while others such as black birch stress stem height growth. By linking the biological data to the physical fire data, post-burn sprouting probability curves are being developed for the most common species and species groups of hardwood regeneration (Figure 3).

The sprouting probability curves show that the different hardwood species can be separated into four groups. The first one contains all hardwood species when the regeneration is quite small (root collar diameter < 0.25 inches). Virtually none of these survive prescribed fire, regardless of species, especially if the fire occurs during mid to late spring. Group 2 are the weak sprouters like black birch and yellow-poplar. The vast majority of the regeneration of Group 2 species fails to sprout after a fire, regardless of root collar diameter. Group 3 are the strong sprouters such as the oaks and hickories. Most of the regeneration of these species will sprout after a fire regardless of duration of the burn or maximum temperature. Group 4 includes the intermediate sprouters – species

like red maple whose sprouting ability is strongly influenced by fire seasonality and intensity. If the fire is not intense and/or occurs during the dormant season, then the likelihood of sprouting is quite high. However, sprouting probability drops if the fire is a spring burn and its intensity is high.

Figure 3. Post-spring fire sprouting probability of black birch, red maple, and red oak as a function of fire duration. Red oak is a species group and includes black oak, northern red oak, and scarlet oak. The numbers 1 and 2 refer to root collar diameter < 0.25 inches and 0.25 – 0.75 inches, respectively.



TECHNOLOGY TRANSFER

Despite the delays that have plagued this project, technology transfer opportunities have been rather frequent from the beginning and show no sign of abating anytime soon. Collectively, the PI and two co-PIs have spoken on over 50 occasions to a wide variety of audiences on different aspects of this study. Audiences have included high school and university students, conservation organizations, federal, state, and tribal land management organizations, forest fire protection councils, landowner groups, and SAF chapters. All three investigators have led numerous tours to some of the more accessible burn sites. Noteworthy visitors include Jim Grace (PA state forester), Sally Collins (Associate Chief of the Forest Service), and Michael Rains (Director of the Northeastern Research Station). Sites in Pennsylvania and West Virginia are routinely used in conjunction with the oak silviculture (SILVAH) shortcourses offered by the Northeastern Research Station (Figure 4). The Pennsylvania sites will also be a major part of the SAF National Convention tours this fall.

Figure 4. Dr. Patrick Brose discussing mountain laurel as a hazardous fuel and regeneration obstacle in oak forests to participants of a silviculture shortcourse.

In accordance with the technology transfer goal of a workshop for practitioners, a 3-day conference on fuels, fire behavior, and fire ecology in oak forests was held in November 2005 at Columbus, Ohio. This conference was attended by over 400 people from 20 eastern states, the vast majority being practicing land managers. The conference proceedings are not yet available but it should be in print by the end of the calendar year. In it, there are several talks and posters presenting preliminary data from this project. A synopsis and evaluation of the conference is already on file with the Joint Fire Science Program and should also be considered as a deliverable of this project. Besides this conference, pertinent published papers are limited to a few preliminary publications in other conference proceedings. These include:

Ward, J.S.; Brose, P.H. 2004. Mortality, survival, and growth of individual stems after prescribed burning in recent hardwood clearcuts. Proceedings of the 14th Central Hardwoods Forest Conference. USDA Forest Service General Technical Report NE-316. Pages 193 – 199. (see included copy)

Brose, P.H.; Miller, G.W.; Gottschalk, K.W. In press. Re-introducing fire to the oak forests of Pennsylvania: response of striped maple. Proceedings of the 2005 National Silviculture Workshop. USDA Forest Service General Technical Report PSW-???

Schuler, T.M.; Ford, W.M.; Adams, M.B. In press. Integrating repeat prescribed fires and deer density control into management of mixed-oak forests. Proceedings of the 2006 Society of American Foresters National Convention.

DELIVERABLES

Proposed Deliverable	Current Status
A multi-day conference on fuels, fire behavior, and fire ecology of oak forests especially geared for practitioners	Fire in Eastern Oak Forests: Delivering Science to Land Managers was held in November 2005 at Columbus, OH. Proceedings to be available in late 2006.
A photo series illustrating the common fuel types of mixed-oak forests published as a Forest Service general technical report.	This deliverable has evolved into two photo series based on additional input from cooperators. One photo series will depict the five fuel types of this study while the other will emphasize logging slash in partially cut stands. Additional funding has been sought to cover the extra cost of producing a second photo series and expected publication of both is 2007. See attached sample page of both photo series.
Updating of SILVAH 5.1 decision charts and prescription recommendations	Five new decision charts were created and SILVAH 5.5 is in beta testing. See attached flow chart for an example. The prescription recommendations are being written into the SILVAH 5.5 User's Guide and it should be published in 2007
Conference and peer-reviewed publications reporting the findings of the project	One "in print" paper and two "in press" papers to date. A copy of the "in print" paper is attached.
A virtual-tour web site of the fuel types and the prescribed fires.	The computer specialist that was to develop the website returned to college to pursue a graduate degree. Work on this deliverable will proceed once a suitable replacement is found.

A sample decision chart from the SILVAH decision-support system showing the new prescribe fire recommendations.