

Photo Guide

for Predicting Fire Risk to Hardwood Trees during Prescribed Burning Operations in Eastern Oak Forests



Abstract

A field guide of 40 photographs of common hardwood trees of eastern oak forests and fuel loadings surrounding their bases. The guide contains instructions on how to rapidly assess a tree's likelihood to be damaged or killed by prescribed burning.

The Author

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Photo Guide for Predicting Fire Risk to Hardwood Trees during Prescribed Burning Operations in Eastern Oak Forests

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Introduction

Throughout the eastern United States, prescribed fire is becoming an accepted practice to help regenerate mixed-oak (*Quercus* spp.) forests (Yaussy 2000, Dickinson 2006, Hutchinson, in press). In this capacity, prescribed fire functions as a site preparation tool in mature stands, helping establish new oak seedlings from acorns, or as a release agent in shelterwood stands, freeing existing oak reproduction from competing vegetation (Brose and others 2006, Brose and others 2008). The use of prescribed fire in either of these manners is problematic because fire can damage and kill overstory trees.

In any fire, overstory damage and mortality varies from trees that are unscathed to ones that die during the burn. Many factors contribute to this variability, but research indicates that fuel arrangement and loading at the base of overstory trees are key factors in determining the degree of fire damage and mortality (Brose and Van Lear 1999, Yaussy and Waldrop, in press). Fortunately, these two fuel characteristics can be controlled by forest managers to minimize fire damage and mortality. The purpose of this photo guide is to help forest managers quickly identify which overstory trees are threatened by fire damage and mortality so time and resources can be concentrated on protecting them and not wasted on trees with little or no risk of fire damage and mortality.

How this photo guide was developed

Prior to burning, 70 overstory trees in eight prescribed fire units in Ohio and Pennsylvania were selected based on visual estimation of varying forest fuel loadings near their trunks. Woody fuels were inventoried around each tree by the time-lag size classes described by Fosberg (1970) along eight 10-foot transects that radiated out from the tree's base like spokes on a wheel.

Woody fuel counts were converted to tons/acre loadings using the standard equations (Brown 1974). Litter fuels were collected from a 14-inch by 14-inch quadrat at the end of each transect, dried at 75°C to a constant weight and weighed to the nearest 0.1 ounce.

The prescribed fires were conducted in late March and early April 2001 by the Ohio Division of Natural Resources, early May 2008 by the Pennsylvania Bureau of Forestry, and mid April 2006 by the Pennsylvania Game Commission. Air temperature during these burns ranged from 60 to 75° F, relative humidity was 25 to 40%, wind was 1 to 3 mph, and the sky was mostly sunny. Moisture of 10-hour woody fuels ranged from 12 to 18%. Generally, flame lengths were between 1 and 2 feet except where logging slash produced 5 to 10 foot flames. Rates of spread ranged from 1 to 5 feet per minute.

After the prescribed fires, each tree was measured for fire damage (height and width of the charred bark), crown health (Gottschalk and McFarlane 1993), and monitored for mortality for three growing seasons. In the case of trees burned in 2007 and 2008, mortality was estimated from the char measurements using a fire-mortality model for upland oaks (Loomis 1973).

The results of the monitoring and estimation indicate that the trees can be placed into one of four risk groups based on their damage, crown condition, and mortality. **The “low risk” trees** exhibited no visible signs of fire damage or minor charring on a small portion of one face. Crowns were healthy and remained so during the 3 years after the fire. Most of these trees only had leaf litter (3 to 5 tons/acre) or light woody fuel loadings (7 to 11 tons/acre) near their bases. A few trees had higher woody fuel loadings (13 to 17 tons/acre)

but the heat from this amount of fuel was offset by other factors such as slope, direction of fire spread, bark thickness so the trees were not injured by the fire.

The “moderate risk” trees had charring on one or two faces (less than half of the bole’s circumference). Crowns remained healthy during the 3 years after the fire. Fuel loadings near these trees ranged from 12 to 29 tons/acre but were usually isolated to just one face. Also, the higher fuel loadings (20 to 29 tons/acre) in this group occurred in conjunction with thick-barked species such as chestnut oak (*Q. montana*) and white oak (*Q. alba*).

“High risk” trees sustained char on at least three faces (more than 50 percent of the bole’s circumference) and had fair or poor crowns, or died within 3 years of the fire. Fuel loadings near these trees ranged from 13 to 36 tons/acre and the fuel usually abutted the trees on two or more faces. Also, the lower fuel loadings (13 to 19 tons/acre) in this group occurred in conjunction with small, thin-barked species such as red maple (*Acer rubrum*) and scarlet oak (*Q. coccinea*).

“Extreme risk” trees died during the first postfire growing season. Fuel loadings ranged from 19 to 50 tons/acre near their bases and fuel arrangement was often on all sides of the trees. Because of these loadings and the resultant sustained intense heat during the prescribed burn, no species was impervious, regardless of bark thickness.

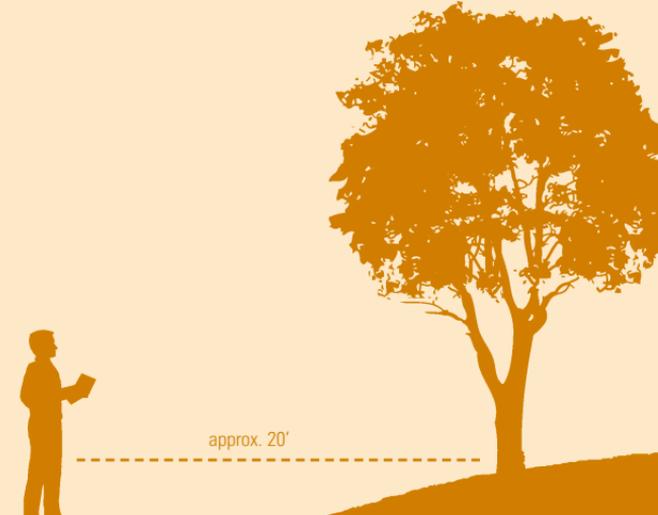
How to use this photo guide

This photo guide will assist forest managers in recognizing trees at risk for fire-caused damage and mortality **before** prescribed burning occurs and can help managers decide whether preventive measures should be taken to protect trees. The photos are arranged in order of increasing total fuel loading within each risk group (low, moderate, high, and extreme).

To use this photo guide, first decide whether a tree is worth protecting according to the overall management goal. If it is, stand about 20 feet away from the tree on the downhill side. Look through the guide and select a photo that closely resembles the fuels you observe. Sometimes, no photo perfectly depicts the field condition. In those cases, select a pair of photos that appear to bracket the observed condition. Look to the lower left corner of the page for the fire risk of the tree you are rating. Generally, trees in the “high” and “extreme” groups need to have the 100-hour and larger fuels within 5 to 10 feet of their bases removed to ensure their survival during most prescribed burning operations.

Remember that a photo guide is an elementary aid for predicting fire damage and mortality. Many factors besides fuel arrangement and loading influence fire damage and mortality so users should bear in mind that this guide depicts only a few of the possible situations. Also, this guide is designed with low- to moderate-intensity spring prescribed fires in mind. Burns conducted at other times of the year and at different intensities will likely produce different results from those depicted in this guide.

Stand about 20 feet away from the tree on the downhill side. Look through the guide and select a photo that closely resembles the fuels you observe.



The photos are arranged in order of increasing total fuel loading within each risk group.



Photo 18: Chestnut oak (23 inch d.b.h.)

Photo by Kristin Brown, U.S. Forest Service

Site Characteristics

Location: Moshannon State Forest,
Clearfield County, Pennsylvania
Date: May 2008

Aspect: South
Slope: 2 %
Slope Position: Middle ?

Fuel Conditions

Litter cover: 100 %

Fuel bed height: 0.5 ft.

Fuel Size and Type

Leaf litter
1-hour woody
10-hour woody
100-hour woody
1000-hour woody
Total fuels

Loading

3.5 tons/acre
0.2 tons/acre
1.2 tons/acre
8.5 tons/acre
11.8 tons/acre
24.3 tons/acre

RISK RATING: **Moderate**

Look to the lower left corner of the page for the fire risk of the tree you are rating.

Acknowledgments

The Ohio Division of Natural Resources, the Pennsylvania Bureau of Forestry, and the Pennsylvania Game Commission assisted in locating the stands used in this project and conducted the prescribed fires. Special thanks are due to Wendy Andersen, Brent Carlson, Josh Hanson, Lance Meyen, Ty Ryen, and Greg Sanford for the preburn fuel sampling and postburn monitoring. Tom Waldrop's and Dan Yaussy's reviews of earlier versions of this manuscript helped with clarity and organization. This research was partially funded by the USDA Forest Service through the Joint Fire Science Program and the National Fire Plan.

References

- Brose, P.H.; Van Lear, D.H. 1999. **Effects of seasonal prescribed fires on residual overstory trees in oak-dominated shelterwood stands.** Southern Journal of Applied Forestry. 23(3): 88-93.
- Brose, P.H.; Schuler, T.M.; Ward, J.S. 2006. **Responses of oak and other hardwood regeneration to prescribed fire: what we know as of 2005.** In: Dickinson, M.B., ed. Fire in eastern oak forests: delivering science to land managers. Gen. Tech. Rep. NRS-1. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station: 123-135.
- Brose, P.H.; Gottschalk, K.W.; Horsley, S.B.; Knopp, P.D.; Kochenderfer, J.N.; McGuinness, B.J.; Miller, G.W.; Ristau, T.E.; Stoleson, S.H.; Stout, S.L. 2008. **Prescribing regeneration treatments for mixed-oak forests of the mid-Atlantic region.** Gen. Tech. Rep. NRS-33. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station: 100 p.

- Brown, J.K. 1974. **Handbook for inventorying downed woody material.** Gen. Tech. Rep. INT-16. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 24 p.
- Dickinson, M.B., ed. 2006. **Fire in eastern oak forests: delivering science to land managers.** Gen. Tech. Rep. NRS-P-1. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station. 303 p.
- Fosberg, M.A. 1970. **Drying rates of wood below fiber saturation.** Forest Science 16: 57-63.
- Gottschalk, K.W.; MacFarlane, W.R. 1993. **Photographic guide to crown conditions: use for gypsy moth silvicultural treatments.** Gen. Tech. Rep. NE-168. Radnor, PA: U.S. Department of Agriculture, Forest Service, Northeastern Research Station. 8 p.
- Hutchinson, T.F., ed. In press. **Proceedings of a workshop: Fire in eastern oak forests: learning from experience.** To be published as a Northern Research Station General Technical Report.
- Loomis, R.M. 1973. **Estimating fire-caused mortality and injury in oak-hickory forests.** Res. Pap. NC-94. St Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station. 6 p.
- Yaussy, D.A., comp. 2000. **Fire, people, and the central hardwood landscape.** Gen. Tech. Rep. NE-274. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northeastern Research Station. 129 p.
- Yaussy, D.A.; Waldrop, T.A. in press. **Delayed mortality of eastern hardwoods after prescribed fire.** In: Stanturf, J.A., ed. Proceedings of the 14th biennial southern silviculture research conference. Gen. Tech. Rep. SRS-. Asheville, NC: U.S. Department of Agriculture, Forest Service, Northern Research Station.

Trees in the “low risk” group exhibited no visible signs of fire damage or minor charring on a small portion of one face. Crowns were healthy and remained so during the 3 years after the fire. Most of these trees only had leaf litter (3 to 5 tons/acre) or light woody fuel loadings (7 to 11 tons/acre) near their bases. A few trees had higher woody fuel loadings (13 to 17 tons/acre) but the heat from this amount of fuel was offset by other factors such as slope, direction of fire spread, bark thickness so the trees were not injured by the fire.

Low Risk



Photo 1: White oak (15-inch d.b.h.)

Photo by Patrick Brose, U.S. Forest Service

Site Characteristics

Location: Vinton Furnace Experimental Forest

Vinton County, Ohio

Date: March 2001

Aspect: Southeast

Slope: 21 %

Slope Position: Upper 1/3

Fuel Conditions

Litter cover: 100 %

Fuel bed height: 0.3 ft.

Fuel Size and Type

Loading

Leaf litter

3.5 tons/acre

1-hour woody

0.1 tons/acre

10-hour woody

0.2 tons/acre

100-hour woody

0.0 tons/acre

1,000-hour woody

0.0 tons/acre

Total fuels

3.8 tons/acre

RISK RATING: **Low**



Photo 2: Black oak (20-inch d.b.h.)

Photo by Patrick Brose, U.S. Forest Service

Site Characteristics

Location: Zaleski State Forest,
Vinton County, Ohio
Date: March 2001

Aspect: Southwest
Slope: 16 %
Slope Position: Middle 1/3

Fuel Conditions

Litter cover: 100 %

Fuel bed height: 0.2 ft.

Fuel Size and Type

Loading

Leaf litter

4.3 tons/acre

1-hour woody

0.4 tons/acre

10-hour woody

0.5 tons/acre

100-hour woody

0.2 tons/acre

1,000-hour woody

0.0 tons/acre

Total fuels

5.4 tons/acre



Photo 3: White oak (22-inch d.b.h.)

Photo by Patrick Brose, U.S. Forest Service

Site Characteristics

Location: Tar Hollow State Forest,
Ross County, Ohio
Date: March 2001

Aspect: Southwest
Slope: 21 %
Slope Position: Upper 1/3

Fuel Conditions

Litter cover: 100 %

Fuel bed height: 0.5 ft.

Fuel Size and Type

Loading

Leaf litter

3.4 tons/acre

1-hour woody

0.4 tons/acre

10-hour woody

0.7 tons/acre

100-hour woody

1.2 tons/acre

1,000-hour woody

1.6 tons/acre

Total fuels

7.3 tons/acre



Photo 4: White oak (20-inch d.b.h.)

Photo by Patrick Brose, U.S. Forest Service

Site Characteristics

Location: Zaleski State Forest,
Vinton County, Ohio
Date: March 2001

Aspect: Southwest
Slope: 8 %
Slope Position: Middle 1/3

Fuel Conditions

Litter cover: 100 %

Fuel bed height: 1.0 ft.

Fuel Size and Type

Loading

Leaf litter

3.5 tons/acre

1-hour woody

0.3 tons/acre

10-hour woody

1.7 tons/acre

100-hour woody

2.3 tons/acre

1,000-hour woody

1.5 tons/acre

Total fuels

9.3 tons/acre

RISK RATING: **Low**



Photo 5: Red maple (22-inch d.b.h.)

Photo by Patrick Brose, U.S. Forest Service

Site Characteristics

Location: Moshannon State Forest,
Clearfield County, Pennsylvania
Date: May 2008

Aspect: South
Slope: 2 %
Slope Position: Middle 1/3

Fuel Conditions

Litter cover: 100 %

Fuel bed height: 0.2 ft.

Fuel Size and Type

Loading

Leaf litter

3.5 tons/acre

1-hour woody

0.1 tons/acre

10-hour woody

0.7 tons/acre

100-hour woody

4.8 tons/acre

1,000-hour woody

1.9 tons/acre

Total fuels

11.0 tons/acre

RISK RATING: **Low**



Photo 6: Red maple (18-inch d.b.h.)

Photo by Patrick Brose, U.S. Forest Service

Site Characteristics

Location: Moshannon State Forest,
Clearfield County, Pennsylvania
Date: May 2008

Aspect: South
Slope: 2 %
Slope Position: Middle 1/3

Fuel Conditions

Litter cover: 100 %

Fuel bed height: 0.2 ft.

Fuel Size and Type

Loading

Leaf litter

3.3 tons/acre

1-hour woody

0.1 tons/acre

10-hour woody

0.6 tons/acre

100-hour woody

3.4 tons/acre

1,000-hour woody

3.7 tons/acre

Total fuels

11.1 tons/acre



Photo 7: White oak (22-inch d.b.h.)

Photo by Patrick Brose, U.S. Forest Service

Site Characteristics

Location: Zaleski State Forest,
Vinton County, Ohio
Date: March 2001

Aspect: Southwest
Slope: 10 %
Slope Position: Middle 1/3

Fuel Conditions

Litter cover: 100 %

Fuel bed height: 1.0 ft.

Fuel Size and Type

Loading

Leaf litter

3.5 tons/acre

1-hour woody

0.4 tons/acre

10-hour woody

1.2 tons/acre

100-hour woody

6.5 tons/acre

1,000-hour woody

2.0 tons/acre

Total fuels

13.6 tons/acre



Photo 8: Black oak (17-inch d.b.h.)

Photo by Patrick Brose, U.S. Forest Service

Site Characteristics

Location: Tar Hollow State Forest,
Ross County, Ohio
Date: March 2001

Aspect: South
Slope: 25 %
Slope Position: Upper 1/3

Fuel Conditions

Litter cover: 100 %

Fuel bed height: 0.6 ft.

Fuel Size and Type

Loading

Leaf litter

3.9 tons/acre

1-hour woody

0.8 tons/acre

10-hour woody

1.3 tons/acre

100-hour woody

5.0 tons/acre

1,000-hour woody

3.4 tons/acre

Total fuels

14.4 tons/acre



Photo 9: White oak (21-inch d.b.h.)

Photo by Patrick Brose, U.S. Forest Service

Site Characteristics

Location: Moshannon State Forest,
Clearfield County, Pennsylvania
Date: May 2008

Aspect: South
Slope: 2 %
Slope Position: Middle 1/3

Fuel Conditions

Litter cover: 100 %

Fuel bed height: 0.2 ft.

Fuel Size and Type

Loading

Leaf litter

3.5 tons/acre

1-hour woody

0.2 tons/acre

10-hour woody

1.2 tons/acre

100-hour woody

8.4 tons/acre

1,000-hour woody

3.3 tons/acre

Total fuels

16.6 tons/acre

The “moderate risk” trees had charring on one or two faces (less than half of the bole’s circumference). Crowns remained healthy during the 3 years after the fire. Fuel loadings near these trees ranged from 12 to 29 tons/acre but were usually isolated to just one face. Also, the higher fuel loadings (20 to 29 tons/acre) in this group occurred in conjunction with thick-barked species such as chestnut oak (*Q. montana*) and white oak (*Q. alba*).

Moderate Risk



Photo 10: Black oak (21-inch d.b.h.)

Photo by Patrick Brose, U.S. Forest Service

Site Characteristics

Location: Vinton Furnace Experimental
Forest, Vinton County, Ohio
Date: March 2001

Aspect: South
Slope: 28 %
Slope Position: Upper 1/3

Fuel Conditions

Litter cover: 100 %

Fuel bed height: 1.5 ft.

Fuel Size and Type

Loading

Leaf litter

3.9 tons/acre

1-hour woody

1.0 tons/acre

10-hour woody

0.8 tons/acre

100-hour woody

2.4 tons/acre

1,000-hour woody

3.4 tons/acre

Total fuels

11.5 tons/acre



Photo 11: Scarlet oak (13-inch d.b.h.)

Photo by Patrick Brose, U.S. Forest Service

Site Characteristics

Location: Vinton Furnace Experimental
Forest, Vinton County, Ohio
Date: March 2001

Aspect: West
Slope: 18 %
Slope Position: Upper 1/3

Fuel Conditions

Litter cover: 98 %

Fuel bed height: 0.3 ft.

Fuel Size and Type

Loading

Leaf litter

3.8 tons/acre

1-hour woody

0.4 tons/acre

10-hour woody

1.9 tons/acre

100-hour woody

4.4 tons/acre

1,000-hour woody

1.3 tons/acre

Total fuels

11.8 tons/acre



Photo 12: American beech (14-inch d.b.h.)

Photo by Patrick Brose, U.S. Forest Service

Site Characteristics

Location: State Game Land 29

Warren County, Pennsylvania

Date: April 2006

Aspect: South

Slope: 2 %

Slope Position: Upper 1/3

Fuel Conditions

Litter cover: 80 %

Fuel bed height: 0.7 ft.

Fuel Size and Type

Loading

Leaf litter

2.1 tons/acre

1-hour woody

0.4 tons/acre

10-hour woody

0.9 tons/acre

100-hour woody

4.1 tons/acre

1,000-hour woody

7.3 tons/acre

Total fuels

14.8 tons/acre



Photo 13: Scarlet oak (23-inch d.b.h.)

Photo by Patrick Brose, U.S. Forest Service

Site Characteristics

Location: Zaleski State Forest

Vinton County, Ohio

Date: March 2001

Aspect: West

Slope: 12 %

Slope Position: Middle 1/3

Fuel Conditions

Litter cover: 100 %

Fuel bed height: 1.3 ft.

Fuel Size and Type

Loading

Leaf litter

3.9 tons/acre

1-hour woody

0.3 tons/acre

10-hour woody

2.4 tons/acre

100-hour woody

8.2 tons/acre

1,000-hour woody

2.2 tons/acre

Total fuels

17.0 tons/acre

RISK RATING: **Moderate**



Photo 14: Chestnut oak (12-inch d.b.h.)

Photo by Patrick Brose, U.S. Forest Service

Site Characteristics

Location: Zaleski State Forest

Vinton County, Ohio

Date: March 2001

Aspect: Southwest

Slope: 18 %

Slope Position: Upper 1/3

Fuel Conditions

Litter cover: 100 %

Fuel bed height: 2.0 ft.

Fuel Size and Type

Loading

Leaf litter

3.7 tons/acre

1-hour woody

0.5 tons/acre

10-hour woody

2.3 tons/acre

100-hour woody

6.5 tons/acre

1,000-hour woody

4.4 tons/acre

Total fuels

17.4 tons/acre



Photo 15: Pignut hickory (10-inch d.b.h.)

Photo by Patrick Brose, U.S. Forest Service

Site Characteristics

Location: Zaleski State Forest

Vinton County, Ohio

Date: March 2001

Aspect: Southwest

Slope: 15 %

Slope Position: Middle 1/3

Fuel Conditions

Litter cover: 95 %

Fuel bed height: 0.7 ft.

Fuel Size and Type

Loading

Leaf litter

3.7 tons/acre

1-hour woody

0.8 tons/acre

10-hour woody

2.0 tons/acre

100-hour woody

7.5 tons/acre

1,000-hour woody

3.5 tons/acre

Total fuels

17.5 tons/acre



Photo 16: Northern red oak (20-inch d.b.h.)

Photo by Patrick Brose, U.S. Forest Service

Site Characteristics

Location: Moshannon State Forest,
Clearfield County, Pennsylvania
Date: May 2008

Aspect: Southwest
Slope: 2 %
Slope Position: Middle 1/3

Fuel Conditions

Litter cover: 100 %

Fuel bed height: 0.5 ft.

Fuel Size and Type

Loading

Leaf litter

3.5 tons/acre

1-hour woody

0.2 tons/acre

10-hour woody

0.9 tons/acre

100-hour woody

4.5 tons/acre

1,000-hour woody

8.9 tons/acre

Total fuels

18.0 tons/acre



Photo 17: Northern red oak (22-inch d.b.h.)

Photo by Patrick Brose, U.S. Forest Service

Site Characteristics

Location: Moshannon State Forest,
Clearfield County, Pennsylvania
Date: May 2008

Aspect: South
Slope: 2 %
Slope Position: Middle 1/3

Fuel Conditions

Litter cover: 100 %

Fuel bed height: 0.6 ft.

Fuel Size and Type

Loading

Leaf litter

3.5 tons/acre

1-hour woody

0.3 tons/acre

10-hour woody

1.5 tons/acre

100-hour woody

6.9 tons/acre

1,000-hour woody

7.1 tons/acre

Total fuels

19.3 tons/acre



Photo 18: Chestnut oak (23-inch d.b.h.)

Photo by Patrick Brose, U.S. Forest Service

Site Characteristics

Location: Moshannon State Forest,
Clearfield County, Pennsylvania
Date: May 2008

Aspect: South
Slope: 2 %
Slope Position: Middle 1/3

Fuel Conditions

Litter cover: 100 %

Fuel bed height: 0.5 ft.

Fuel Size and Type

Loading

Leaf litter

3.5 tons/acre

1-hour woody

0.3 tons/acre

10-hour woody

1.2 tons/acre

100-hour woody

8.5 tons/acre

1,000-hour woody

11.8 tons/acre

Total fuels

24.3 tons/acre



Photo 19: Chestnut oak (16-inch d.b.h.)

Photo by Patrick Brose, U.S. Forest Service

Site Characteristics

Location: Zaleski State Forest,
Vinton County, Ohio
Date: March 2001

Aspect: Southwest
Slope: 15 %
Slope Position: Middle 1/3

Fuel Conditions

Litter cover: 100 %

Fuel bed height: 3.2 ft.

Fuel Size and Type

Loading

Leaf litter

4.4 tons/acre

1-hour woody

0.8 tons/acre

10-hour woody

1.6 tons/acre

100-hour woody

11.0 tons/acre

1,000-hour woody

10.7 tons/acre

Total fuels

28.5 tons/acre

“High risk” trees sustained char on at least three faces (more than 50 percent of the bole’s circumference) and had fair or poor crowns, or died within 3 years of the fire. Fuel loadings near these trees ranged from 13 to 36 tons/acre and the fuel usually abutted the trees on two or more faces. Also, the lower fuel loadings (13 to 19 tons/acre) in this group occurred in conjunction with small, thin-barked species such as red maple (*Acer rubrum*) and scarlet oak (*Q. coccinea*).

High Risk



Photo 20: Scarlet oak (10-inch d.b.h.)

Photo by Patrick Brose, U.S. Forest Service

Site Characteristics

Location: Vinton Furnace Experimental Forest

Vinton County, Ohio

Date: March 2001

Aspect: Southwest

Slope: 20 %

Slope Position: Upper 1/3

Fuel Conditions

Litter cover: 100 %

Fuel bed height: 1.2 ft.

Fuel Size and Type

Loading

Leaf litter

3.5 tons/acre

1-hour woody

0.2 tons/acre

10-hour woody

1.7 tons/acre

100-hour woody

5.3 tons/acre

1,000-hour woody

2.6 tons/acre

Total fuels

13.3 tons/acre



Photo 21: Scarlet oak (13-inch d.b.h.)

Photo by Patrick Brose, U.S. Forest Service

Site Characteristics

Location: Vinton Furnace Experimental Forest

Vinton County, Ohio

Date: March 2001

Aspect: Southwest

Slope: 20 %

Slope Position: Upper 1/3

Fuel Conditions

Litter cover: 100 %

Fuel bed height: 1.5 ft.

Fuel Size and Type

Loading

Leaf litter

4.2 tons/acre

1-hour woody

0.4 tons/acre

10-hour woody

1.7 tons/acre

100-hour woody

6.1 tons/acre

1,000-hour woody

3.8 tons/acre

Total fuels

16.2 tons/acre



Photo 22: Red maple (11-inch d.b.h.)

Photo by Patrick Brose, U.S. Forest Service

Site Characteristics

Location: Moshannon State Forest,
Clearfield County, Pennsylvania
Date: May 2008

Aspect: South
Slope: 5 %
Slope Position: Middle 1/3

Fuel Conditions

Litter cover: 100 %

Fuel bed height: 0.8 ft.

Fuel Size and Type

Loading

Leaf litter

3.3 tons/acre

1-hour woody

0.2 tons/acre

10-hour woody

2.1 tons/acre

100-hour woody

6.6 tons/acre

1,000-hour woody

7.1 tons/acre

Total fuels

19.3 tons/acre



Photo 23: Northern red oak (22-inch d.b.h.)

Photo by Patrick Brose, U.S. Forest Service

Site Characteristics

Location: Moshannon State Forest,
Clearfield County, Pennsylvania
Date: May 2008

Aspect: Northwest
Slope: 2 %
Slope Position: Middle 1/3

Fuel Conditions

Litter cover: 100 %

Fuel bed height: 1.2 ft.

Fuel Size and Type

Loading

Leaf litter

3.5 tons/acre

1-hour woody

0.2 tons/acre

10-hour woody

1.6 tons/acre

100-hour woody

11.6 tons/acre

1,000-hour woody

6.2 tons/acre

Total fuels

23.1 tons/acre



Photo 24: White oak (20-inch d.b.h.)

Photo by Patrick Brose, U.S. Forest Service

Site Characteristics

Location: Zaleski State Forest,
Vinton County, Ohio
Date: March 2001

Aspect: Southwest
Slope: 16 %
Slope Position: Middle 1/3

Fuel Conditions

Litter cover: 100 %

Fuel bed height: 1.5 ft.

Fuel Size and Type

Loading

Leaf litter

3.6 tons/acre

1-hour woody

0.3 tons/acre

10-hour woody

1.3 tons/acre

100-hour woody

11.6 tons/acre

1,000-hour woody

6.9 tons/acre

Total fuels

23.7 tons/acre



Photo 25: White oak (14-inch d.b.h.)

Photo by Patrick Brose, U.S. Forest Service

Site Characteristics

Location: Zaleski State Forest,
Vinton County, Ohio
Date: March 2001

Aspect: Southwest
Slope: 11 %
Slope Position: Middle 1/3

Fuel Conditions

Litter cover: 100 %

Fuel bed height: 3.5 ft.

Fuel Size and Type

Loading

Leaf litter

3.9 tons/acre

1-hour woody

0.7 tons/acre

10-hour woody

3.6 tons/acre

100-hour woody

12.1 tons/acre

1,000-hour woody

3.9 tons/acre

Total fuels

24.2 tons/acre



Photo 26: Red maple (14-inch d.b.h.)

Photo by Patrick Brose, U.S. Forest Service

Site Characteristics

Location: State Game Land 29,
Warren County, Pennsylvania
Date: April 2006

Aspect: South
Slope: 2 %
Slope Position: Upper 1/3

Fuel Conditions

Litter cover: 100 %

Fuel bed height: 1.3 ft.

Fuel Size and Type

Loading

Leaf litter

3.3 tons/acre

1-hour woody

0.6 tons/acre

10-hour woody

1.1 tons/acre

100-hour woody

9.5 tons/acre

1,000-hour woody

14.6 tons/acre

Total fuels

26.1 tons/acre

RISK RATING: **High**



Photo 27: Northern red oak (15-inch d.b.h.)

Photo by Patrick Brose, U.S. Forest Service

Site Characteristics

Location: Moshannon State Forest,
Clearfield County, Pennsylvania
Date: May 2008

Aspect: South
Slope: 2 %
Slope Position: Middle 1/3

Fuel Conditions

Litter cover: 100 %

Fuel bed height: 0.7 ft.

Fuel Size and Type

Loading

Leaf litter

3.4 tons/acre

1-hour woody

0.3 tons/acre

10-hour woody

2.0 tons/acre

100-hour woody

13.5 tons/acre

1,000-hour woody

7.7 tons/acre

Total fuels

26.9 tons/acre



Photo 28: Pignut hickory (7-inch d.b.h.)

Photo by Patrick Brose, U.S. Forest Service

Site Characteristics

Location: Tar Hollow State Forest,
Ross County, Ohio
Date: March 2001

Aspect: South
Slope: 30 %
Slope Position: Middle 1/3

Fuel Conditions

Litter cover: 100 %

Fuel bed height: 2.1 ft.

Fuel Size and Type

Loading

Leaf litter

3.1 tons/acre

1-hour woody

0.3 tons/acre

10-hour woody

2.9 tons/acre

100-hour woody

11.5 tons/acre

1,000-hour woody

9.2 tons/acre

Total fuels

27.0 tons/acre

RISK RATING: **High**



Photo 29: Chestnut oak (24-inch d.b.h.)

Photo by Patrick Brose, U.S. Forest Service

Site Characteristics

Location: Vinton Furnace Experimental Forest,
Vinton County, Ohio
Date: March 2001

Aspect: Northeast
Slope: 33 %
Slope Position: Upper 1/3

Fuel Conditions

Litter cover: 100 %

Fuel bed height: 3.3 ft.

Fuel Size and Type

Loading

Leaf litter

4.0 tons/acre

1-hour woody

0.2 tons/acre

10-hour woody

1.2 tons/acre

100-hour woody

18.5 tons/acre

1,000-hour woody

10.5 tons/acre

Total fuels

34.1 tons/acre



Photo 30: Northern red oak (24-inch d.b.h.)

Photo by Patrick Brose, U.S. Forest Service

Site Characteristics

Location: Moshannon State Forest,
Clearfield County, Pennsylvania
Date: May 2008

Aspect: South
Slope: 2 %
Slope Position: Middle 1/3

Fuel Conditions

Litter cover: 90 %

Fuel bed height: 0.6 ft.

Fuel Size and Type

Loading

Leaf litter

3.4 tons/acre

1-hour woody

0.1 tons/acre

10-hour woody

1.0 tons/acre

100-hour woody

6.3 tons/acre

1,000-hour woody

25.7 tons/acre

Total fuels

36.5 tons/acre

“Extreme risk” trees died during the first postfire growing season. Fuel loadings ranged from 19 to 50 tons/acre near their bases and fuel arrangement was often on all sides of the trees. Because of these loadings and the resultant sustained intense heat during the prescribed burn, no species was impervious, regardless of bark thickness.

Extreme Risk



Photo 31: Red maple (6-inch d.b.h.)

Photo by Patrick Brose, U.S. Forest Service

Site Characteristics

Location: Tar Hollow State Forest,
Ross County, Ohio
Date: March 2001

Aspect: Southeast
Slope: 23 %
Slope Position: Middle 1/3

Fuel Conditions

Litter cover: 100 %

Fuel bed height: 1.5 ft.

Fuel Size and Type

Loading

Leaf litter

2.1 tons/acre

1-hour woody

0.6 tons/acre

10-hour woody

2.0 tons/acre

100-hour woody

9.3 tons/acre

1,000-hour woody

5.2 tons/acre

Total fuels

19.2 tons/acre



Photo 32: Pignut hickory (7-inch d.b.h.)

Photo by Patrick Brose, U.S. Forest Service

Site Characteristics

Location: Vinton Furnace Experimental Forest,
Vinton County, Ohio
Date: March 2001

Aspect: South
Slope: 28 %
Slope Position: Upper 1/3

Fuel Conditions

Litter cover: 100 %

Fuel bed height: 4.5 ft.

Fuel Size and Type

Loading

Leaf litter

3.5 tons/acre

1-hour woody

0.3 tons/acre

10-hour woody

1.0 tons/acre

100-hour woody

14.4 tons/acre

1,000-hour woody

7.4 tons/acre

Total fuels

26.6 tons/acre



Photo 33: Northern red oak (15-inch d.b.h.)

Photo by Patrick Brose, U.S. Forest Service

Site Characteristics

Location: Moshannon State Forest,
Clearfield County, Pennsylvania
Date: May 2008

Aspect: South
Slope: 2 %
Slope Position: Middle 1/3

Fuel Conditions

Litter cover: 80 %

Fuel bed height: 1.4 ft.

Fuel Size and Type

Loading

Leaf litter

3.3 tons/acre

1-hour woody

0.2 tons/acre

10-hour woody

1.8 tons/acre

100-hour woody

7.7 tons/acre

1,000-hour woody

20.1 tons/acre

Total fuels

33.1 tons/acre



Photo 34: Northern red oak (15-inch d.b.h.)

Photo by Patrick Brose, U.S. Forest Service

Site Characteristics

Location: Moshannon State Forest,
Clearfield County, Pennsylvania
Date: May 2008

Aspect: South
Slope: 2 %
Slope Position: Middle 1/3

Fuel Conditions

Litter cover: 80 %

Fuel bed height: 1.4 ft.

Fuel Size and Type

Loading

Leaf litter

2.8 tons/acre

1-hour woody

0.1 tons/acre

10-hour woody

0.9 tons/acre

100-hour woody

9.0 tons/acre

1,000-hour woody

26.5 tons/acre

Total fuels

39.3 tons/acre



Photo 35: Chestnut oak (16-inch d.b.h.)

Photo by Patrick Brose, U.S. Forest Service

Site Characteristics

Location: Moshannon State Forest,
Clearfield County, Pennsylvania
Date: May 2008

Aspect: South
Slope: 2 %
Slope Position: Middle 1/3

Fuel Conditions

Litter cover: 100 %

Fuel bed height: 1.1 ft.

Fuel Size and Type

Loading

Leaf litter

3.5 tons/acre

1-hour woody

0.2 tons/acre

10-hour woody

1.3 tons/acre

100-hour woody

6.9 tons/acre

1,000-hour woody

28.3 tons/acre

Total fuels

40.2 tons/acre



Photo 36: Red maple (11-inch d.b.h.)

Photo by Patrick Brose, U.S. Forest Service

Site Characteristics

Location: Moshannon State Forest,
Clearfield County, Pennsylvania
Date: May 2008

Aspect: South
Slope: 2 %
Slope Position: Middle 1/3

Fuel Conditions

Litter cover: 100 %

Fuel bed height: 1.8 ft.

Fuel Size and Type

Loading

Leaf litter

3.4 tons/acre

1-hour woody

0.3 tons/acre

10-hour woody

1.5 tons/acre

100-hour woody

18.8 tons/acre

1,000-hour woody

16.8 tons/acre

Total fuels

40.8 tons/acre



Photo 37: Northern red oak (12-inch d.b.h.)

Photo by Patrick Brose, U.S. Forest Service

Site Characteristics

Location: Moshannon State Forest,
Clearfield County, Pennsylvania
Date: May 2008

Aspect: South
Slope: 2 %
Slope Position: Middle 1/3

Fuel Conditions

Litter cover: 100 %

Fuel bed height: 2.1 ft.

Fuel Size and Type

Loading

Leaf litter

3.5 tons/acre

1-hour woody

0.2 tons/acre

10-hour woody

1.5 tons/acre

100-hour woody

12.1 tons/acre

1,000-hour woody

25.2 tons/acre

Total fuels

42.5 tons/acre



Photo 38: Black oak (21-inch d.b.h.)

Photo by Patrick Brose, U.S. Forest Service

Site Characteristics

Location: Tar Hollow State Forest,
Ross County, Ohio
Date: March 2001

Aspect: South
Slope: 30 %
Slope Position: Middle 1/3

Fuel Conditions

Litter cover: 100 %

Fuel bed height: 4.0 ft.

Fuel Size and Type

Loading

Leaf litter

4.5 tons/acre

1-hour woody

0.8 tons/acre

10-hour woody

2.9 tons/acre

100-hour woody

18.9 tons/acre

1,000-hour woody

18.6 tons/acre

Total fuels

45.7 tons/acre



Photo 39: Northern red oak (22-inch d.b.h.)

Photo by Patrick Brose, U.S. Forest Service

Site Characteristics

Location: State Game Land 29,
Warren County, Pennsylvania
Date: April 2006

Aspect: South
Slope: 2 %
Slope Position: Upper 1/3

Fuel Conditions

Litter cover: 85 %

Fuel bed height: 2.5 ft.

Fuel Size and Type

Loading

Leaf litter

2.9 tons/acre

1-hour woody

0.5 tons/acre

10-hour woody

1.8 tons/acre

100-hour woody

13.4 tons/acre

1,000-hour woody

27.6 tons/acre

Total fuels

46.2 tons/acre



Photo 40: Scarlet oak (24-inch d.b.h.)

Photo by Patrick Brose, U.S. Forest Service

Site Characteristics

Location: Zaleski State Forest,
Vinton County, Ohio
Date: March 2001

Aspect: West
Slope: 10 %
Slope Position: Middle 1/3

Fuel Conditions

Litter cover: 100 %

Fuel bed height: 4.2 ft.

Fuel Size and Type

Loading

Leaf litter

4.0 tons/acre

1-hour woody

1.4 tons/acre

10-hour woody

3.2 tons/acre

100-hour woody

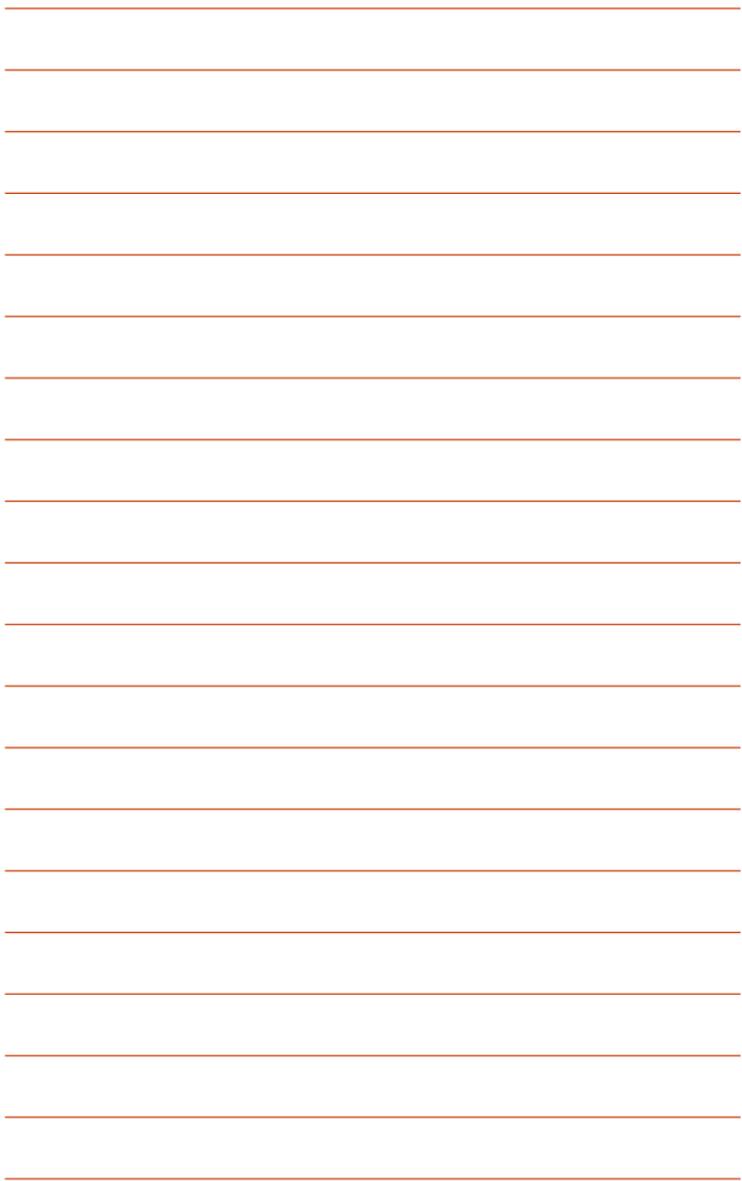
23.4 tons/acre

1,000-hour woody

18.3 tons/acre

Total fuels

50.3 tons/acre



Brose, Patrick H. 2009. **Photo guide for estimating risk to hardwood trees during prescribed burning operations in eastern oak forests.** Gen. Tech. Rep. NRS-44. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station. 95 p.

A field guide of 40 photographs of common hardwood trees of eastern oak forests and fuel loadings surrounding their bases. The guide contains instructions on how to rapidly assess a tree's likelihood to be damaged or killed by prescribed burning.

KEY WORDS: forest fire, forest fuels, *Quercus*, shelterwood system

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