

THE VIABILITY OF RESERVE TREES AND STUMP SPROUTING  
ON DRY, NUTRIENT-POOR OAK SITES

BY

ELIJAH K. MUJURI

A THESIS

SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENT OF THE  
DEGREE

MASTER OF SCIENCE

IN

NATURAL RESOURCES (NATURAL RESOURCE  
MANAGEMENT)

COLLEGE OF NATURAL RESOURCES

UNIVERSITY OF WISCONSIN

STEVENS POINT, WISCONSIN

AUGUST 2008

APPROVED BY THE GRADUATE COMMITTEE OF:

---

DR. MICHAEL C. DEMCHIK, COMMITTEE CHAIRMAN  
ASSOCIATE PROFESSOR OF FORESTRY

---

DR. ERIC M. ANDERSON  
PROFESSOR OF WILDLIFE ECOLOGY

---

DR. JAMES E. COOK  
PROFESSOR OF FORESTRY AND FOREST ECOLOGY

---

DR. PAUL F. DORUSKA  
ASSOCIATE PROFESSOR OF FORESTRY

## **PREFACE**

This paper manuscript is written in the format of Northern Journal of Applied Forestry

## ABSTRACT

Low quality oak growing on dry, nutrient poor sites, colloquially called scrub oak, constitutes a common forest type in Central Wisconsin. Northern pin oak (*Quercus ellipsoidalis*) is one of the dominant tree species on these sites. It is shade intolerant and an effective stump sprouter; however, it is also short-lived. The combination of effective stump sprouting and shade intolerance suggests coppice as one of the soundest silvicultural practices for use with this species. However, many of the associated tree species that grow on these sites, such as white pine (*Pinus strobus*), white oak (*Q. alba*) and bur oak (*Q. macrocarpa*), tend to be longer-lived and more shade tolerant.

The potential for retaining a percentage of these longer-lived trees as reserve trees has not been well researched. Because these longer-lived species also tend to have slower growth rates, retention of them for a longer period of time than the standard rotation length of 45-70 years will allow them to reach sawlog size and also provide improved habitat for wildlife and better aesthetics. Because of the desirability of maintaining some reserve trees on these sites, one of the objectives of this research endeavor is to assess the persistence (as demonstrated by health and growth rate) of reserve trees for a 15 year time period after the surrounding stand was harvested. Two species of reserve trees were selected for use in this study: white oak and northern pin oak. Reserve trees that result from harvests which occurred over a 15 year timeframe were assessed for volume growth, crown condition, vigor and epicormic branching. This assessment indicated that white oak makes an excellent reserve tree with improvement in periodic annual increment (PAI; an index of volume growth) and vigor. Northern pin oak improved in PAI, indicating a positive growth response to the release; however, tree vigor declined through

time after release. This corresponded well with our expectations based on the autecology of both species. Northern pin oak is a relatively fast-growing species with early maturity and quick senescence. White oak, by contrast, is a relatively slow-growing species, with late maturity and delayed senescence. Both species appear to be viable species for use as reserve trees; however, where white oak is present, it will make a far superior reserve tree because it has the ability to improve in both vigor and growth rate after release.

Because stump sprouting is the dominant form of regeneration in a coppice harvest system for oaks, determining the rate of stump sprouting for the dominant species is essential. This information is lacking for northern pin oak in Wisconsin. The objective of the second portion of this study is to determine the expected sprouting rate of northern pin oak on scrub oak sites. Northern pin oak stumps were assessed for sprouting on four recent harvest sites (winter of 2006 and 2007). Overall, northern pin oak was found to sprout at a high frequency (overall average of 84.7%). As stump diameter increased, frequency of sprouting decreased; however, even for large stumps, the frequency of sprouting was quite high (over 70%). With sprouting frequencies that are this high on sites where oaks are very competitive, only moderate amounts of advanced regeneration would be necessary for a site to restock after harvest.

The results from first studies suggest that retention of reserve trees can be quite viable in scrub oak sites. Additionally, the frequency of stump sprouting of the dominant vegetation in these sites, northern pin oak, was found to be quite high. The combination of high frequency of stump sprouting and good viability of reserve trees suggests the need for future research with the use of “coppice with standard” harvest system on scrub oak sites.

## **ACKNOWLEDGEMENTS**

These projects were funded in whole by McIntire-Stennis Cooperative Research Grant. It could not have been possible without the support Dr. Michael Demchik, a dear friend and my mentor, for his professional and academic guidance. I am deeply grateful to the support of Drs. Paul Doruska, James Cook and Eric Anderson for their insightful and academic guidance without which the study could not be accomplished. In my two years at the UWSP, I have interacted with most of the teaching staff and students who have been very helpful in a unique way. I take this opportunity to thank all of them for the friendship, love and support that was unlimited.

I also thank the Wisconsin DNR foresters who have been very supportive of this research. My appreciation especially goes to Mark Chryst, WI DNR Forester, Wood County, Marcia Frost Vahradian, and Brad Kildow, WI DNR Forest Rangers at Waushara and Portage Counties respectively for their support and assistance.

Special thanks to Dr. Jan Harms, Associate Professor of Forestry and Forestry Coordinator, for offering me the position of Graduate Teaching Assistant and funding my first year of graduate school, through the forestry faculty.

My sincere and deepest thanks are to my family members who have always been there for me. I am most indebted to my parents and my parent's in-law and their families for their support, encouragement and motivation. The project could not be completed without the support of my wonderful and lovely wife Doris, and the love from my two boys Steven and Brian, who I watch every morning with joy and love after a long night keeping me awake. You have always given me a reason to smile even when the world seemed to be closing on me. Thank you for allowing me to achieve my dreams.

# TABLE OF CONTENTS

PREFACE.....	iii
ABSTRACT.....	iv
ACKNOWLEDGEMENTS.....	vi
TABLE OF CONTENTS.....	vii
LIST OF TABLES.....	ix
LIST OF FIGURES .....	x
CHAPTER 1: GENERAL INTRODUCTION .....	1
CHAPTER 2: ASSESSING THE VIABILITY OF NORTHERN PIN OAK AND WHITE OAK RESERVE TREES 15 YEARS AFTER HARVESTING RELEASE ON DRY NUTRIENT-POOR SITES OF CENTRAL WISCONSIN.....	6
ABSTRACT .....	6
INTRODUCTION.....	7
METHODS AND SITE SELECTION .....	11
DATA ANALYSIS .....	16
RESULTS.....	18
DISCUSSION.....	25
CONCLUSIONS .....	31
LITERATURE CITED.....	32

CHAPTER 3: NORTHERN PIN OAK STUMP SPROUTING FREQUENCY ON	
SCRUB OAK SITES OF CENTRAL WISCONSIN .....	37
ABSTRACT .....	37
INTRODUCTION .....	38
METHODS AND SITE SELECTION .....	40
RESULTS .....	42
DISCUSSION AND CONCLUSION .....	46
LITERATURE CITED .....	48
CHAPTER 4 : CONCLUSION .....	50
RESERVE TREES .....	50
NORTHERN PIN OAK STUMP SPROUTING.....	51
LITERATURE CITED .....	52

## LIST OF TABLES

Table 1: Frequencies of visual health assessment for northern pin oak (NPO) and white oak (WO) reserve trees up to 15 years after harvest in the period 1990 and 2007... 19	19
Table 2: p-values from Chi-Square tests of visual health assessment for northern pin oak and white oak reserve trees 15 years after harvest in the period 1990 and 2007. All comparisons were made to reserve trees from a 2005-2006 harvest period..... 20	20
Table 3: Average Periodic Annual Increments and the corresponding p-values associated with paired t-test: two samples assuming equal variances; with two-tailed distribution for northern pin and white oak reserve trees over period of 15 years since cutting release. The comparison is for the five years before and the five years after the harvest..... 24	24
Table 4: Estimated coefficients, standard error of estimated coefficients, p-values and 95% confidence intervals for the binary logistic regression model predicting the probability of northern pin oak sprouting from diameter (in.)..... 43	43
Table 5: Observed and predicted northern pin oak sprouting (%) for various parent stump diameter classes in scrub oak sites of central Wisconsin..... 44	44
Table 6: Observed (Obs) and estimated expected (Exp) frequencies within each decile of sprouting defined by fitted value for sprout present and no sprout present as developed by the binary logistic regression software. .... 45	45

## LIST OF FIGURES

- Figure 1: Mean annual increment and periodic annual increment for (a) northern pin oak and (b) white oak reserve trees within Meadow Valley/Sandhill Wildlife Area..... 23
- Figure 2. (a) Diameter and (b) age distribution of northern pin oak and white oak reserve trees assessed for visual health and growth over a 15 year window since release. .. 27

LIST OF APPENDIX

Appendix 1: Overstory survey form for reserve trees ..... 54

## CHAPTER 1

### GENERAL INTRODUCTION

Wisconsin generates 12% of its gross state product from forest products and forest-based recreation. A total of 16 million acres of Wisconsin are in forest cover. This landbase is under numerous forms of public and private-ownership; however, the majority is privately owned (WI DNR 2006). This pattern of forestland ownership is mirrored across much of the United States where 42% of the forestland is privately-owned (Butler and Leatherberry 2004). Across the United States, only 4% of these privately-owned parcels have management plans (Butler and Leatherberry 2004); however, in Wisconsin, a much greater percentage of the landbase is under active management. In Wisconsin, 2.9 million acres (approximately 18%) have management plans developed through just two tax-relief programs: Forest Crop Law (FCL) and Managed Forest Law (MFL). Active management of the forestland contributes to the prominence of forestry in the economy of Wisconsin.

Because Wisconsin has such a large percentage of its privately-owned forestlands under management plans, silvicultural harvests directed at reaching specific landowner goals represent a sizable fraction of the total harvests in the state. While timber harvest is widespread, and is often required through involvement in tax relief programs such as MFL, landowners usually own their land for reasons other than timber harvest. These reasons for landownership frequently include aesthetics and wildlife habitat (Kuuluvainen et al. 1996; Butler and Leatherberry 2004). Developing management

prescriptions that can address multiple landowner goals and still keep this privately-owned forestland productive is important to the economy of Wisconsin.

On dry, nutrient-poor sites in Central Wisconsin, scrub oak is a common forest cover. On these sites, regeneration after harvest is often predictably good. This is partly because oaks are far more competitive than many other tree species on poor quality sites. On richer, more mesic soils, oak regeneration is often outcompeted by fast growing and shade tolerant species (WI DNR 2006).

While advanced regeneration plays an important role in the revegetation of harvested scrub oak sites, stump sprouts often provide the majority of the successful regeneration. Surprisingly, though stump sprouting plays a dominant role in the regeneration of northern pin oak (*Quercus ellipsoidalis*; one of the main species on scrub oak sites), little research has documented the frequency of stump sprouting. We could only find one study (Lynch and Bassett 1987) in the Lake States that focused on northern pin oak stump sprouting on dry, nutrient-poor sites in Michigan. Generally, Lynch and Bassett (1987) found northern pin oak stump sprouting rates of 77% and the sprouting was independent of stump diameter. The independence of stump sprouting from stump diameter is a rather novel finding, although occasionally reported for some species. Sprouting of most oaks and other hardwoods however, has generally been found to be dependent on parent stump diameter (Roth and Hepting 1943; Johnson 1975, 1977; Sander et al. 1976). At least one other researcher has documented equal sprouting across all diameters. Wendel (1975) also found sprouting of northern red oak to be unimpacted by diameter for trees less than 80 years old. The limited past research on northern pin oak stump sprouting combined with the relative importance of stump sprouting to the

regeneration of northern pin oak stimulated us to initiate one of the two projects in this thesis.

The relative ease of regeneration on these sites has resulted in rather simple prescriptions for regeneration (Sander 1977; Sander et al. 1984). The current management prescriptions recommended by the WI DNR (WI DNR 2006) are coppice with up to two reserve trees per acre and shelterwood cut in sites of higher site index (50 to 55 feet at 50 years) with rotational ages of 45 to 70 years. While these prescriptions are favorable for short-lived species (notably northern pin oak), the other associated species growing on these sites (white oak [*Q. alba*], bur oak [*Q. macrocarpa*] eastern white pine [*Pinus strobus*] and red pine [*P. resinosa*]) are quite long-lived (Shifley and Smith 1982; Burns and Honkala 1990). If these long-lived species are left as reserve trees, they are likely to grow large enough to contain sawlogs (albeit low-grade logs). The retention of reserve trees can also satisfy many landowners' goals related to wildlife management and aesthetics.

Landowners are often reluctant to harvest. However, with enrollment in the MFL, periodic cutting of timber is mandatory. Most of the scrub oak parcels that are in the MFL are rather small (the average size of ownership is 100 acres with the minimum size of 10 acres; Nielsen and Bergmann 2004), and are frequently past recommended rotation age (Kotar 1997; Kotar et al. 1999). The small parcel sizes and the advanced age of these stands significantly reduce possible management options. Often, coppice harvest of the entire parcel is the only practical option. As a compromise that better addresses the wildlife and aesthetics goals of the landowners, the MFL currently allows retention of up to two trees per acre in its prescription for scrub oaks (WI DNR 2006).

While retention of reserve trees is allowed to better meet landowner goals, studies were not found that have followed the response of reserve trees on scrub oak sites through time. Surviving and maintaining good vigor would be imperative to the success of reserve trees. While other studies have addressed survival of reserve trees on better quality sites (Starkey and Guldin 2004; Miller et al. 2006), survival of reserve trees on scrub oak sites would most likely be quite different. Because these sites are usually dominated by short-lived species (northern pin oak) and are often past biological rotation age, the trees on these sites are frequently in various stages of decline. Retention of healthy trees that can survive until the next stand entry (in 45-70 years) would be expected to be challenging. Retention of the longer-lived associates in these stands (white and bur oak, white and red pine) would seem to be more prudent. Of the scrub oak sites in Wisconsin's forest inventory analysis (FIA) plots, nearly 70% had greater than 5% of the pole/sawlog size trees as bur or white oak (USDA Forest Service 2006). Documenting the health and growth response of reserve trees remaining after a harvest on scrub oak sites would provide useful information for foresters creating harvest prescriptions for use on private lands.

One of the goals of this project was to evaluate the health and growth of reserve trees remaining after harvest on scrub oak sites. The second goal of this project is to document the frequency of sprouting for northern pin oak stumps and to determine if sprouting is dependent on stump diameter. The specific objectives of this project are to assess:

- a) vigor, survival and growth response of selected species of reserve trees growing on dry, nutrient-poor oak sites; and

- b) the sprouting potential of stumps in different diameter classes for northern pin oak in the dry, nutrient-poor, oak sites of Central Wisconsin.

## CHAPTER 2

# **ASSESSING THE VIABILITY OF NORTHERN PIN OAK AND WHITE OAK RESERVE TREES 15 YEARS AFTER HARVESTING RELEASE ON DRY NUTRIENT-POOR SITES OF CENTRAL WISCONSIN**

## ABSTRACT

Most of the scrub oak sites in Wisconsin are managed for wildlife management and aesthetics objectives other than timber production and inclusion of reserve trees can help address those objectives. The objective of the study was to determine the growth and health response of northern pin and white oak held as reserve trees from harvests occurring over a 15 year time period on scrub oak sites. Reserve trees resulting from previously harvested scrub oak sites in Meadow Valley and Sandhill Wildlife Areas in Central Wisconsin were assessed for volume growth and various health attributes of epicormic branching, live crown ratio and tree vigor. All the white oaks reserve trees in the study were alive and had much epicormic branching that allowed them to build much larger crowns after release. Northern pin oak had an overall annual mortality rate of 5.5% which is considered to be excessive. From this assessment, white oaks appeared to make an excellent reserve tree based on improvements in periodic annual increment, improvement of vigor, and increases in live crown ratio after release. Northern pin oak, while still a viable reserve tree, tended to respond to release with a decline in overall tree health potentially due to normal age-related senescence.

**Keywords:** Scrub oak, coppice, *Quercus*, mortality

## INTRODUCTION

In the dry, nutrient-poor sands of Central Wisconsin, scrub oak is a common forest cover. Scrub oak sites are defined by the Wisconsin Department of Natural Resources as sites with greater than 50% oak and site index (SI) of less than 50 feet at 50 years (WI DNR 2006). Due to the low soil quality, the oaks on these sites are generally poorly-formed and are usually of quality suited only for fuelwood, pulpwood and tie-grade logs (WI DNR 2006). The sites are usually dominated by northern pin oak (*Quercus ellipsoidalis*) and/or black oak (*Q. velutina*), with common associates composed of white oak (*Q. alba*), eastern white pine (*Pinus strobus*) and red maple (*Acer rubrum*). The dominant trees (northern pin and black oak) are quite short-lived with suggested rotation ages of 45-70 years, while some of the associates like white pine and white oak can be quite long-lived (Shifley and Smith 1982; Burns and Honkala 1990). Often complicating the management of these sites is their advanced age. The majority of Wisconsin scrub oak stands are at or past optimal rotation age (Kotar 1997; Kotar et al. 1999). The short lifespan and low timber value of the dominant vegetation on scrub oak sites combined with their current advanced age limits management options for these stands.

The current management options as prescribed by Wisconsin Department of Natural Resources (WI DNR) in the Silviculture and Forest Aesthetics Handbook (WI DNR 2006) are quite restricted. These options include coppice with reserves of up to two trees per acre, and shelterwood cut in sites where site index is higher (50 to 55 feet at 50 years) with rotation ages of 45 to 70 years. The simplicity of the current harvest prescriptions is possible due to a high capacity for stump sprouting from the mature trees

and a general presence of adequate and competitive advance regeneration (Sander 1977). Both northern pin oak and black oak tend to sprout at rates in excess of 60% (Lynch and Bassett 1987; Sander et al. 1976, 1984) across broad sizes and ages of cut trees. Additionally, stumps from young, small diameter trees usually sprout at the highest frequency (Baughman and Jacobs 1992; Sander et al. 1976, 1984; Johnson 1977, 1994). With a rotation age of 45-70 years, the stumps are both young and small and therefore likely to sprout at a very high frequency. Additionally, advanced regeneration is both generally present and more competitive under these site conditions. While it is often true that oak stands meeting the minimum requirement for advance regeneration are rare in other soil conditions (Sander et al. 1976; Steiner et al. 2008), scrub oak sites tend to have abundant advance regeneration (Sander and Clark 1971; Sander et al. 1976). Oak seedlings are also more likely to become part of the canopy of the scrub oak sites as they are well adapted to these droughty, low nutrient conditions. Oaks have better competitive advantage on low site index sites (Cook et al. 1998). Due to the high sprouting frequency and good competitive abilities for the advanced regeneration, low quality sites usually regenerate to oak (Sander et al. 1984).

While coppice harvest is biologically viable for scrub oak sites, it often conflicts with the landowner's goals regarding aesthetics and wildlife habitat. This conflict has resulted in a general reluctance by landowners to harvest sites (WI DNR 2006). This is especially apparent and problematic in scrub oak because the optimal rotation is quite short (45-70 years) and growth of economic trees decline begins quickly after this age is passed (WI DNR 2006). Because many of these scrub oak sites are under the MFL program, a property tax relief program, the landowners are obligated to follow good

forest management practices as detailed in the *Silviculture and Forest Aesthetics Handbook* (WI DNR 2006). Most of the scrub oak parcels that are in the MFL are rather small (the average size of ownership is 100 acres with the minimum size of 10 acres; Nielsen and Bergmann 2004), causing operational constraints on the large-scale equipment needed to economically harvest low-value material like oak pulpwood and tie grade logs. With the size of the parcels and the advanced age of the stands, coppice harvest of the entire parcel is often the only practical option. This option, however, is often contrary to the landowner's desired post-harvest stand condition. Coppice on a 45-70 year rotation may also conflict with the economic returns for one or more species within the stand, especially white oak and white pine (Johnson 2004). It is doubtful that white oak (a notoriously slow-growing tree) or white pine (a species with a much longer potential rotation on these sites [WI DNR 2006]) has neared economic or biological maturity before the dominant cover of northern pin oak and/or black oak has begun to decline or die. One possible solution to this conflict is retention of reserve trees. To better meet multiple landowner objectives, the MFL currently allows retention of up to two trees per acre in their prescription for scrub oak (Johnson et al. 1998; WI DNR 2006).

Longevity is one of the requirements for a good reserve tree. While short-lived black or northern pin oaks tend to dominate scrub oak sites, other longer-lived species (white oak and white pine) are a component of many of these sites. Of the Wisconsin's FIA plots on scrub oaks sites, nearly 70% had greater than 5% of the pole/sawlog size trees as bur (*Q. macrocarpa*) or white oak (USDA Forest Service 2006). Mortality of the reserve trees could reduce the silvicultural acceptability of retaining them; however, Starkey and Guldin (2004) in a study of shortleaf pine (*P. echinata*)-hardwood forest type

in Ouachita and Ozark forest in Arkansas, found mortality of reserves to be a minor problem with 91.5% survival 5 years after harvest. In Appalachian mixed hardwoods, Miller et al. (2006) found that 90% of reserve trees survived after 20 years. Further, Wargo et al. (1983) showed decline of white oaks to be much less common than decline of species within the red oak group. This conclusion is supported by anecdotal accounts from foresters working in the Central Sands region of Wisconsin who suggest that both northern pin and black oak tend to die over the long-term when left as reserve trees but that white oak and white pine tend to survive.

White and northern pin oaks are a study in contrasts. White oak trees are slow growing with greater shade tolerance and longevity than their counterparts in the red oak group (Shifley and Smith 1982; Shifley et al. 2006). White oaks are intermediate in shade tolerance and can persist under suppression for a long period while maintaining the ability to respond well after release (Rogers 1990). Northern pin oak, by contrast, rarely reproduces under their own shade (Pregitzer and Ramm 1984; Abrams 1988; WI DNR 2006). White oaks have a maximum lifespan of more than 500 years and can respond well to release up to 150 years of age (Trimble 1975; Rogers 1990; Hicks 1998). Northern pin oaks are short-lived and respond quickly to release, but this capacity declines as they approach maturity (Hill 2000). These characteristics suggest that white oak may perform well as reserve trees but that northern pin oak may not.

In this paper we assessed the health, vigor and periodic annual increment (PAI) for northern pin oak and white oak reserve trees over a 15 year period after release. These reserve trees were left after harvest on scrub oak cover types within the Sandhill and Meadow Valley State Wildlife Areas in Central Wisconsin. Our goal was to

determine whether northern pin oak and white oak could be retained as viable reserve trees.

## **METHODS AND SITE SELECTION**

### **Study Site**

Two state managed wildlife areas that have a history of oak harvest with substantial retention of reserve trees were used for this study: Meadow Valley State Wildlife Area (57,600 acres) and Sandhill State Wildlife Area (9,460 acres). The two properties are managed as one unit under the Sandhill-Meadow Valley Work Unit by the Wisconsin Department of Natural Resources (WI DNR) with the primary objective of wildlife management and a secondary goal of timber production. A significant percentage of the forest cover of these wildlife areas fits the criteria of dry, nutrient-poor oak (scrub oak) sites. Meadow Valley and Sandhill Wildlife Areas lie within the old glacial Lake Wisconsin and are generally flat with low sandy ridges. The area has a high water table (approximately 3-5 feet deep). The soils within the Meadow Valley and Sandhill Wildlife Management Area are Friendship, a Mixed, Frigid Typic Udipsamments; Meehan, a Mixed, Frigid Aquic Udipsamments; Plainfield, a Mixed, Mesic Typic Udipsamments; AuGres, a Mixed, Frigid Typic Endoaquod and Newson, a Mixed, Frigid Humaquoptic Psammaquent.

Meadow Valley Wildlife Area was logged in the late 1800's, drained and farmed; however, unpredictable crop failures combined with low soil quality and high tax rates assessed to cover the cost of drainage caused many of the farms to be abandoned. The

abandoned land was later bought by the Federal Government, leased to the State of Wisconsin and administered under an agreement with the United States Fish and Wildlife Service (US FWS). Most of the area is now in forest cover.

Sandhill Wildlife Area is flat and has both forests and wetlands. The area was historically converted to farms and cranberry fields by early settlers after logging of the white and red pine and oak. Later, the farmers were driven away by the problems of high soil acidity, wildfires, summer frost, high drainage taxes and the depression of 1930s. The abandoned land was bought in the 1930's by Wallace Grange who later sold it to State of Wisconsin as a wildlife demonstration area.

By the 1930s, the two properties experienced the effects of a large fire and multiple windstorms that cleared over 12 800 acres. This was followed by reseeded with pine and regeneration with aspen (*Populus* species), oak, ash (*Fraxinus* species), and jack pine (*P. banksiana*)<sup>1</sup>.

Because Meadow Valley and Sandhill Wildlife Management Areas are primarily managed as wildlife habitat, retention of reserve trees has been an important consideration in harvest prescriptions. The logging prescription for oaks in the Meadow Valley/Sandhill Wildlife Area has been to leave all white and bur oaks that are 5 inches or greater in diameter as well as marked reserve trees (mostly composed of northern pin oak and an occasional black and red oak). This history of reserve tree retention provided the opportunity to assess a 15 year chronology of reserve tree response to release.

---

<sup>1</sup> Mark Chryst, Forester, Wood County, Wisconsin Department of Natural Resources, personal communications, June 12, 2007.

## **Plot Establishment/Methods**

We chose to assess northern pin and white oak reserve trees. Because the Wisconsin Department of Natural Resources (WI DNR) maintains timber harvest records for these sites that date back to the 1950s, this enabled us to cover a broad chronology of harvests in the Meadow Valley/Sandhill Wildlife Management Areas. Due to difficulties in locating suitable harvest areas cut more than 15 years ago, the study was restricted to assessing the response of reserve trees for a period of only 15 years after harvest. We reviewed all timber harvest records from the 1950's until 2007. To select potential sites from this rather large number of harvests, we developed a set of criteria. Criteria for consideration for a potential study site included: 1) an oak cover type with site index less than 55 ft at 50 years, 2) harvest records indicating the retention of reserve trees, and 3) adequate harvest area (at least 5 acres) to include sufficient reserve trees for the study. Records for all sites meeting these criteria were studied in detail. After initial site visits to verify the condition of the sites, a suitable chronology was available to assess condition for sites harvested 0, 5, 10 and 15 years previously, with harvest periods (HP) of 2005 to 2006  $\approx$  0 years, 2000 to 2001  $\approx$  5 years, 1995 to 1996  $\approx$  10 years and 1990 to 1991  $\approx$  15 years. In total 16 plots of average 10-15 acres, were selected, four plots per HP with two replicate plots for northern pin oak reserve trees and two replicate plots for white oak reserve trees. Transects were walked on each of these plots and trees within 10 feet of the transect were selected for study. Transects were walked until 20 reserve trees of the desired species were selected for each plot. In total, we sampled 320 trees. For each reserve tree, we extracted an increment core; and measured diameter at breast height (DBH) using a diameter tape and total tree height using a clinometer. Additionally, we

assessed 1) epicormic branching (EB) and 2) live crown ratio (live crown length to total height; LCR) and 3) tree vigor (TV), using the following classes.

1. Presence of epicormic branching was categorized into three classes a) main bole, first stick (first 8 ft. of bole), b) main bole, second stick (in the second 8 ft. of bole), and c) higher than first two sticks.
2. Live crown ratio for each tree was recorded into ocularly-assessed categories of 1- 25, 26-50, 51- 75 or 76- 100%.
3. Tree vigor was determined using criteria of observation based on Gottschalk and MacFarlane (1993): “a) good crown: tree has healthy foliage, less than 25% dead branches, and little or no epicormic branching with no evidence of canker, b) fair crown: 25 to 49% of the branches are dead, foliage density, size and coloration are subnormal or some evident of epicormic branching, c) poor crown: where 50 % or more of branches are dead, foliage density, size and coloration is subnormal or heavy epicormic branching and obvious canker, and d) dead: no crown and tree is dead”.

Increment cores were mounted to wooden blocks, air-dried and sanded. Radial growth was measured in 5 year increments on the cores using electronic calipers. In order to estimate outside bark cubic foot volume of each tree, species-specific cubic foot volume models for the Central States were used (Hahn and Hansen 1992). Volume was estimated as;

$$V_{\text{gross}} = b_1 S^{b_2} (1 - e^{b_3 D^{b_4}}), \quad (1)$$

where  $V_{gross}$  is the estimated gross cubic foot volume,  $D = dbh$  (in.),  $S =$  tree site index (50 ft. at 50 years),  $e = 2.7128$ ,  $b_1$ ,  $b_2$ ,  $b_3$ , and  $b_4$  are species specific parameters from Hahn and Hansen (1992).

In order to estimate diameter outside bark (dob) from increment core measurements for use in the volume equation, the inside bark diameter (dib) was divided by 0.91 (Hilt 1979).

The estimated gross cubic foot volumes were used to determine individual tree mean annual increment (MAI) and periodic annual increment (PAI), according to;

$$PAI = \frac{V_{gross}(t_2) - V_{gross}(t_1)}{5 \text{ years}} \quad (2)$$

$$MAI = \frac{V_{gross}}{age} \quad (3)$$

Where  $V_{gross}$  is the gross cubic feet volume of a tree at a specified time, and  $t_2$  and  $t_1$  are specified times of tree growth at 5 year intervals, while age is the tree age at a specified time. The point where PAI and MAI are equal is called the culmination point. The culmination point represents the point of maximal annual volume growth. For each tree, individual MAI/PAI curves were plotted to determine if the culmination point had been reached.

To determine if the individual reserve trees responded to the stand harvest with increased growth, the volume growth during the five year period prior to harvest was compared to the volume growth during the five year periods after harvest.

## DATA ANALYSIS

The null hypotheses for this study were that the qualitative attributes, EB, LCR and TV for the reserve trees would remain the same across times since harvest (HP). To test these hypotheses, the qualitative parameters for reserve trees were analyzed by contingency tables with: 1) the qualitative attributes as the response variable and 2) time since harvest as the main factor. The results of these analyses were used to determine whether individual tree health improved or declined after the cutting operation. The values for the qualitative parameters measured for reserve trees from HP 2005-2006 were used as the base for the analysis of changes. The qualitative parameters for reserve trees from HP 5, 10 and 15 years were compared to qualitative parameters for trees harvested in HP 0 and data used to determine if there was a decline or an improvement in visual health, tested at  $\alpha = 0.05$  significance level, with the hypothesis that:

$H_0$ : Visual health of reserve trees remains the same after harvesting release, and

$H_1$ : visual health of reserve trees changes after harvest release.

Contingency tables were used to compare the response of the reserve trees during the HP 2005-2006 (as before) and after the harvesting (HP5, 10, and 15), using  $\chi^2$  test. The  $\chi^2$  distribution associated with a  $\chi^2$  test at the relevant degrees of freedom gave us the p-values (upper-tailed probability of the Chi Square distribution).

$$\chi^2_{obs} = \sum_{i=1}^k \frac{(\text{observed count} - \text{expected count})^2}{\text{expected count}} \sim \chi^2_{(k-1)}, \quad (4)$$

where  $k$ , the number of categories of EB, LCR or TV, and  $(k - 1)$  is the relevant degrees of freedom.

The data from increment cores were tested with paired t tests at  $\alpha = 0.05$  significance level, for response to release for white and northern pin oak reserve trees before and after the release, with two sets of hypotheses tested:

1.  $H_0$ : mean PAI for reserve trees remains the same after harvesting release  
 $H_1$ : mean PAI for reserve trees changes after harvesting release
2.  $H_0$ : mean MAI for reserve trees remains the same after harvesting release  
 $H_1$ : mean MAI for reserve trees changes after harvesting release

### **Repeated Measures**

Since time order of reserve trees of 0, 5, 10 and 15 years cannot be randomized, pairs of repeated measures of time on the same reserve tree are likely to be correlated. Observations adjacent in time are assumed to have a larger correlation than the pairs of observations more separated in time (Kuehl 2000). Therefore, observations in time 0 and 5 years are assumed to have more correlation than those observations at time 0 and 15 years. In this study, these differences are accounted for by the assumption that there are equal variances for the treatments groups and reserve trees are independent of each other.

# RESULTS

## **Epicormic Branching**

Most of the white oak reserve tree (over 75%) had epicormic branching within the first 8 feet of the main bole (Table 1). The presence of epicormic branching did not vary through time after release for all periods (Table 2). Northern pin oak epicormic branching did not reflect any major changes during the HP. The majority of the EB appeared within the first 16 ft log, a trend that was maintained within the HP (Table 1). Although the changes for northern pin oak epicormic branching were significant (Table 2), they did not follow any predictable pattern over time (HP). Epicormic branching for the northern pin oak reserve trees within the first 8 ft log, were at lower levels in comparison to those of the white oak reserve trees (Table 1). However, there was less epicormic branching for northern pin oak reserve trees (Table 2).

Table 1: Frequencies of visual health assessment for northern pin oak (NPO) and white oak (WO) reserve trees up to 15 years after harvest in the period 1990 and 2007.

Time	Species	<u>Epicormic branching</u>				<u>Live crown ratio</u>					<u>Tree vigor</u>			
		0	1	2	3	0	1	2	3	4	1	2	3	4
0 years	NPO	1	15	16	8	3	7	20	10	0	0	20	17	3
	WO	0	33	5	2	0	4	16	20	0	34	6	0	0
5 years	NPO	1	6	21	12	2	2	17	19	0	1	34	3	2
	WO	0	35	2	3	0	0	1	17	22	35	5	0	0
10 years	NPO	5	14	13	8	5	5	15	15	0	0	13	22	5
	WO	0	30	5	5	0	0	0	15	25	35	5	0	0
15 years	NPO	4	17	8	11	4	0	20	15	1	8	18	10	4
	WO	0	30	7	3	0	0	0	13	27	38	2	0	0

Key

Epicormic branching

- 0. Tree is dead
- 1. Main bole, first stick
- 2. Main bole, second stick
- 3. Higher than first two sticks

Live crown ratio classes

- Class 0: No crown, tree dead
- Class 1: 1 - 25% crown present
- Class 2: 26 - 50% crown present
- Class 3: 51 - 75% crown present
- Class 4: 76 - 100% crown present

Tree Vigor

- 1. Good crown
- 2. Fair crown
- 3. Poor crown
- 4. No crown and tree is dead

Table 2: p-values from Chi-Square tests of visual health assessment for northern pin oak and white oak reserve trees 15 years after harvest in the period 1990 and 2007. All comparisons were made to reserve trees from a 2005-2006 harvest period

Time since Cutting	Year Cut	Species	Epicormic Branching	Live Crown Ratio	Tree Vigor
5 years	2001, 2002	NPO	0.03	0.01	<0.001
	1999, 2002	WO	0.30	<0.001	0.66
10 years	1992, 1996	NPO	<0.001	0.13	0.07
	1995, 1997	WO	0.09	<0.001	0.66
15 years	1991, 1994	NPO	<0.001	0.02	<0.001
	1990, 1991	WO	0.58	<0.001	0.08

### **Live Crown Ratio (LCR)**

The majority of white oak reserve trees (90%) from HP0 (harvesting period of 2005-2007) had a LCR of 26 -75% (Table 1). This live crown ratio increased to between 50-100% ([p<0.001] Table 2) during the harvest periods 5, 10 and 15 years after release (Table 1). Almost half, 74 of the white oak reserve trees had LCR of 76-100%, 65 had 51-75%, 17 had 26-50% and 4 had 1-25% (Table 1). LCR can either increase via height growth or epicormic branching. However, EB for white oaks did not experience significant changes (Table 2). All white oak reserve trees within the sample unit were alive. By contrast 14 northern pin oak reserve trees were dead (Table 1). In total, among the 160 northern pin oak reserve trees, the majority had LCR less than 50%; 1 had 76-100%, 59 had 51-75%, 72 had 26-50%, 14 had 1-25% and 14 had 0% (Table 2). While white oak live crown ratios tended to increase after release, northern pin oak live crown ratios tended to decline.

### **Tree Vigor**

White oak maintained high TV which improved over time such that almost all reserve trees were in vigor class 1 in the last period examined. By contrast, northern pin oak appeared to decline in tree vigor, a trend that increases over time (Table 1). Among the 160 white oak reserve tree sampled, 88.75% were in the vigor class 1. The other 11.25% reserve trees were in vigor class 2. By contrast among the northern pin oak reserve trees, 5.6, 53.1, 32.5 and 8.8% were in vigor classes 1, 2, 3, and 4, respectively. The 14 in vigor class 4 were already dead (Table 2). Generally, white oak reserve tree TV improved over time while the northern pin oak reserve tree TV declined over time.

## **Periodic Annual Increment**

Neither northern pin nor white oak reserve trees appear to have reached the culmination point based on individual tree data (Figure 1a and b), as PAI is still above MAI when plotted. However, individual tree culmination point may not indicate stand based culmination point. A stand-based culmination point is based on all trees alive/harvestable at any point in time. An individual tree's culmination point can be much later than a stand's culmination point because volume loss due to tree mortality is included in stand-based culmination points and excluded from an individual tree's culmination point. Reserve trees from both species had an increase in PAI following release in almost all cases except for the white oaks during HP 15 which tended to increase during the first 5 years of growth after release, but the increase was not significant ( $P>0.05$ ; Table 3). This increase in PAI persisted through time for all HP.

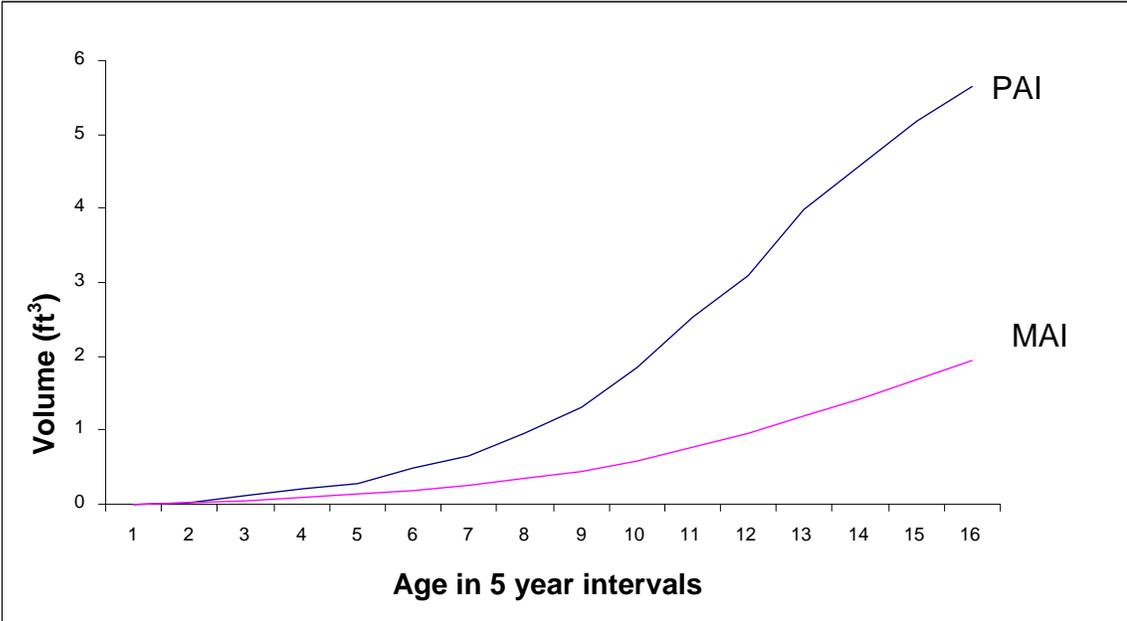
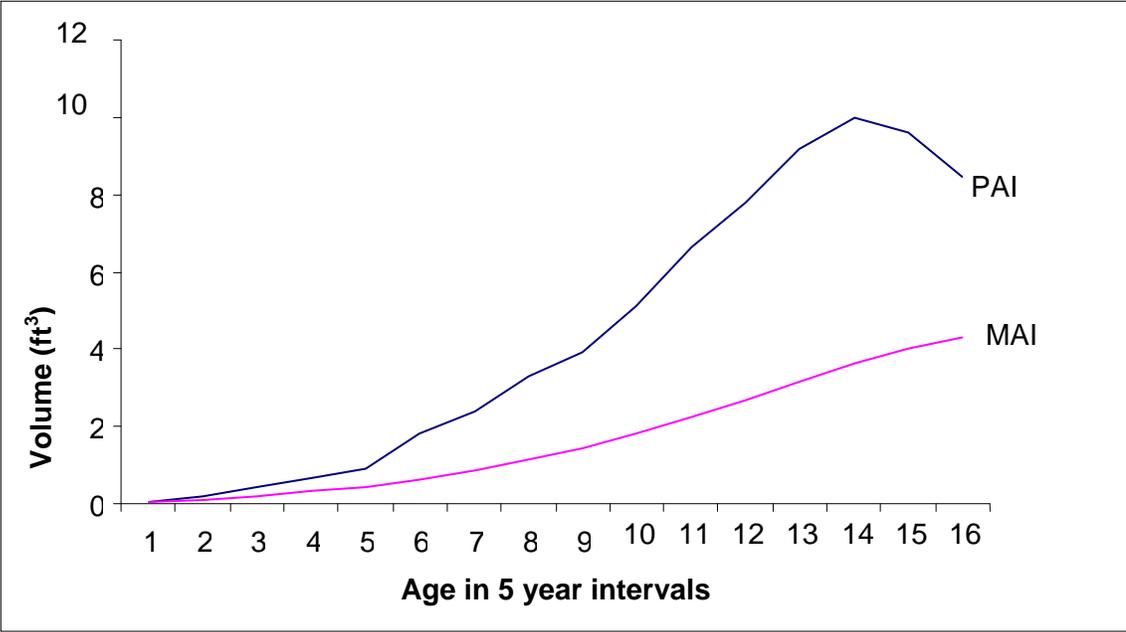


Figure 1: Plot average Mean annual increment and periodic annual increment for (a) northern pin oak and (b) white oak reserve trees within Meadow Valley/Sandhill Wildlife Area

Table 3: Average Periodic Annual Increments and the corresponding p-values associated with paired t-test: two samples assuming equal variances; with two-tailed distribution for northern pin and white oak reserve trees over period of 15 years since cutting release. The comparison is for the five years before and the five years after the harvest.

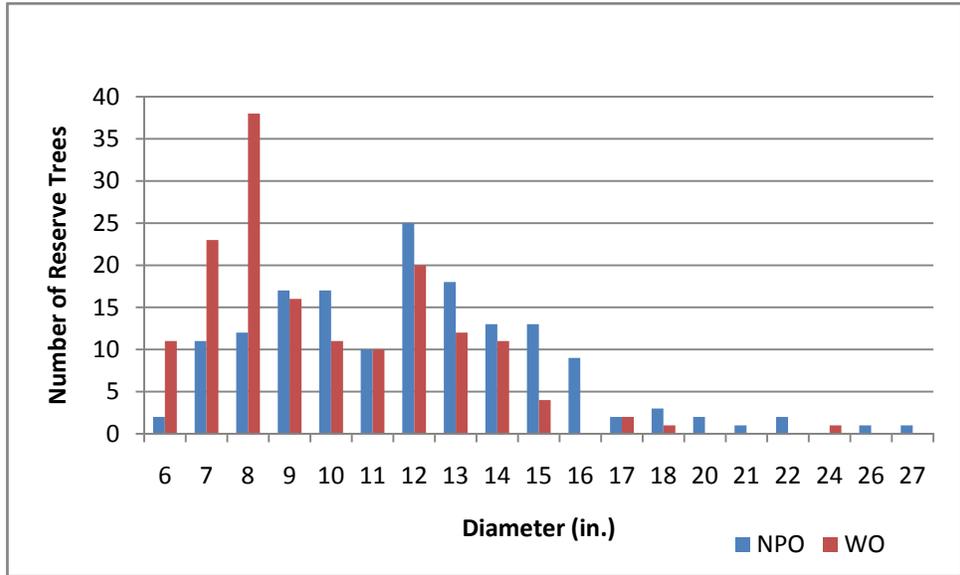
PAI as an annual figure with 5 year base Annual volume growth (ft. <sup>3</sup> )										
		5 Years			10 Years			15 Years		
Year	Species	Mean PAI		p-value	Mean PAI		p-value	Mean PAI		p-value
Cut		Before	After		Before	After		Before	After	
2001	NPO	4.0506	6.2283	0.0020						
1999	WO	0.6839	1.3448	0.0127						
1992	NPO	0.7515	1.5108	0.0305	0.7515	2.3751	0.0030			
1996	NPO	2.3750	3.8620	0.0235	2.3750	4.8956	0.0004			
1995	WO	1.7931	3.2165	0.0147	1.7931	3.6787	0.0015			
1997	WO	0.8221	1.9093	0.0079						
1994	NPO	0.7394	1.5794	0.0075	0.7394	2.0348	0.0011			
1991	NPO	0.2507	0.7215	0.0009	0.2507	1.1100	<0.0001	0.2507	1.6658	<0.0001
1991	WO	0.9743	1.6502	0.1924	0.9743	2.1043	0.0374	0.9743	2.4656	0.0083
1990	WO	0.9386	1.5867	0.0893	0.9386	2.0282	0.0105	0.9386	2.4979	0.0011

## DISCUSSION

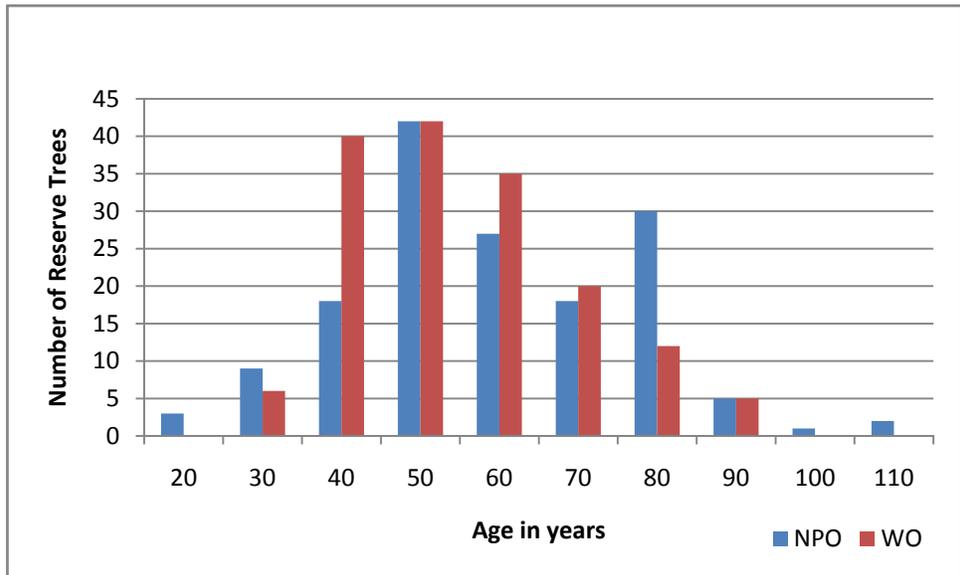
White oak maintained high levels of health based on all attributes assessed for the first 15 years after release. Overall, their health appeared to increase after release. By contrast, northern pin oak reserve trees tended to deteriorate in health after release. Epicormic branching appeared to be a significant issue for white oak; however, the presence of epicormic branching (assessed via live crown ratio) resulted in larger crowns after release. White oak's predisposition to epicormic branching is widespread and not restricted only to those trees growing on scrub oak sites (Smith 1965; Trimble and Seegrist 1973). Because white oak growing on scrub oak sites is not destined to be marketed as higher grade logs but is usually sold as pulpwood, fuelwood and tie-grade logs, epicormic branches are more of an annoyance for the logger than a significant value degrade for the log. No predictable increase in epicormic branching was seen in northern pin oak. While about half of the northern pin oak had epicormic branching in the bottom 16 feet of the bole, this did not increase with time (Table 1). In contrast to white oak, northern pin oak branches appeared to die after release as LCR and TV deteriorated. This reduction in TV and LCR indicates a decline in overall tree health. As a possible result of this health decline, the number of dead northern pin oak reserve trees increased over time. While mortality is normal as a stand ages, mortality rates for oaks are often in the range of 1 to 2 percent per decade (Kabrick et al. 2004). Nichols (1968) stated that mortality rates of over 5% should be considered excessive. Using the average annual mortality return rate formula, (Leuschner 1984), our overall annual rate of mortality was approximately 5.5%. While some increase in mortality might be expected initially as a response to the stress of release, this rate is much higher than expected. Starkey and

Guldin (2004) found 91.5% survival of reserve trees 5 years after harvest, which, using the same protocol, equates to an average annual mortality rate of 1.7%. Miller et al. (2006) found 90% survival for reserve trees 20 years after harvest which equates to 0.5% annual mortality rate. The mortality rate that we found for northern pin oak strongly exceeds the estimated background rate of mortality (1 to 2% per decade) and also exceeds rates of mortality specific to reserve trees (0.5-1.7%) extrapolated from Miller et al. (2006) and Starkey and Guldin (2004). We believe the increase in overall tree health for white oak (indicated by TV and LCR) combined with no measured mortality for white oak in this study demonstrates good potential for use of white oak as reserve trees in shrub oak management. Northern pin oak, while still a potentially valuable reserve tree, experienced tree decline and possibly accelerated mortality. Over the 15 year window of time after release, the northern pin oak was still rather persistent and could still provide valuable ecological services; however, when held for a long time, white oaks are better than their counterpart northern pin oaks.

In the study area, the criterion for selecting the reserve trees by WI DNR foresters is different between the two species. For northern pin oak, reserve trees are selected from trees in the dominant and co-dominant crown class. This selection criterion is used because northern pin oak is the dominant species in these stands, often composing 90% of the mature trees. For white oak, the reserve trees can be as small 5 in. dbh. This is due in part to a lower overall rate of occurrence for white oak. White oak is also perceived to be of higher value for wildlife habitat, because of its greater longevity. While this could have resulted in a heavily skewed distribution, it did not. White oak is somewhat more heavily represented in the smaller size classes than northern pin oak



(a)



(b)

Figure 2. (a) Diameter and (b) age distribution of northern pin oak and white oak reserve trees assessed for visual health and growth over a 15 year window since release.

(Figure 2a); however, this would be expected due to white oak's slower growth rate. When the age distribution is considered (Figure 2b), northern pin oak and white oak are quite similar. On these sites, there may be a bias in initial crown class in that white oak may be more heavily represented by trees in the suppressed/intermediate crown class prior to harvest; however, this is an attribute that we were not able to control in the study. Generally, suppressed and overtopped white oaks are considered to be poor candidates for reserve trees because they have low growth rates, and large, potentially degrading epicormic branching (McGee 1981; McGee and Bivens 1984). The high epicormic branching and high live crown ratio could be problematic in other ecosystems; however, the low log value that is inherent to scrub oak sites would limit the economic impact of increased epicormic branching. Additionally, the presence of epicormic branching in white oak was nearly universal (present on over 75% of the trees) and was therefore not restricted to trees in lower crown classes.

Most of the reserve trees of both species examined responded with increased volume growth after release as evidenced by an increase in PAI. This increase in growth has been noted in many studies of reserve/residual trees (Smith and Lamson 1977; Shifley and Smith 1982; Muir et al. 2002; Davis et al. 2007; Keane et al. 2007). Furthermore, the increase in volume growth after release was noted for all time periods after harvest except for the first five year period for trees released in 1990-91 (HP 0) (Table 3). This period coincides with a severe drought according to the Palmer Drought Severity Index (NOAA/ National Climate Data Center 2008). During this drought period, increased tree mortality and decline was noted on other sites across the state. The increase in volume growth is not surprising for white oak. White oak is a long-lived

species and these white oaks most likely have not reached their biological maturity. Furthermore, with the increase in LRC and TV, these trees would reasonably be expected to respond to the release with greatly increased volume growth. The significant increase in northern pin oak volume growth after release, in spite of a general decline in LRC and TV, is somewhat puzzling. The decline in tree health is not unexpected as these trees are approaching or exceeding their biological maturity (Hicks 1998; Shifley et al. 2006). Stand decline and tree mortality being coincident with increased growth has been found by other researchers. Shifley et al. (2006) noted that rapid dbh growth for the red oak group favors their survival in the short term but may contribute to their mortality in the long term, as it may decrease their ability to tolerate periodic droughts. This is supported by the findings by Jenkins and Pallardy (1995) who found that mortality was greater for trees that grew fast for many years prior to drought than for those that grew slowly. One explanation for this behavior is the complex interaction of drought, and physiological maturity of northern pin oak. This pattern was not apparent in white oak. In a Missouri Ozark oak forest, the overall mortality was four to six times greater for study trees in the red oak group than for study trees in the white oak group (Shifley et al. 2006). The most plausible explanation is that the trees were in an early stage of decline prior to release. After release, the trees experienced significantly reduced competition which allowed them to increase growth rate; however, this increased growth was insufficient to adequately offset decline as these trees passed biological maturity.

Conventional thought regarding the scrub ecosystem is that it is even-aged (WI DNR 2006). However, the ages of these reserve trees ranged from 35 to 110 years (Figure 2b). The age range indicates an uneven-aged structure. While disturbance history

is undoubtedly a partial source of this age range, most other explanations of the uneven age nature of these stands would be solely conjecture. Some of the reserve trees are surviving residuals from a time prior to the winds, fire, logging and farming of the 1930s. These residuals and the cohort from the 1930's are the two main cohorts of northern pin oak in these stands. The white oak appears to have been serially recruited and represent several cohorts. This uneven-age structure results from a complicated stand history; however, this complicated age structure is not restricted to these Wildlife Areas. We found similar age distributions on numerous other sites across 7 counties in Central Wisconsin and this may be a rather common trend.

Based on our results, both northern pin oak and white oak have shown to be acceptable reserve trees. White oak, however, appears to be a superior reserve tree because it exhibits improved growth rate and increased overall tree health. Northern pin oak can also be a very acceptable reserve tree (at least those from the dominant and co-dominant crown classes); however, mortality and overall health decline is much higher. In conditions where white oak is limited, northern pin oak can potentially serve as a quality reserve tree.

## CONCLUSIONS

White oak had excellent response to retention as a reserve tree with improvement in volume growth after release. While white oak had high potential for epicormic branching within the main bole, this may not harm its timber value because the highest grade logs from scrub oak sites are usually only tie-grade logs with the majority of the wood being sold as pulpwood or fuelwood. Overall, white oak appeared to be an appropriate species to use as reserve trees on scrub oak sites. Northern pin oak, by contrast, made an acceptable reserve tree but tended to fail over the long-term. Northern pin oak reserve trees declined in health after release and appeared to be destined to a slow mortality and reduced vigor over time after release. This large difference was most likely due to different biological maturities between the two species. For landowners wishing to maintain reserve trees, white oak across a broad age range and initial live crown ratio range can serve as quality reserve trees. Northern pin oak, while still viable reserve trees, are much less desirable due to long-term health decline and accelerated mortality.

## LITERATURE CITED

- Abrams, M. D. 1988. Comparative water relations of three successional hardwood species in central Wisconsin. *Tree Physiology*. 4(3): 263-273.
- Baughman, M. J., and R. D. Jacobs. 1992. Oak regeneration. Available online: <http://www.extension.umn.edu/distribution/naturalresources/DD5936.html>. Last accessed Sept, 2008.
- Burns, R. M., and B. H. Honkala (eds.). 1990. *Silvics of North America vol.2*. USDA. FS. Agric. Handb. 654. Washington. DC. Available online: [http://na.fs.fed.us/spfo/pubs/silvics\\_manual/volume\\_2/vol2\\_Table\\_of\\_contents.htm](http://na.fs.fed.us/spfo/pubs/silvics_manual/volume_2/vol2_Table_of_contents.htm). Last accessed Sept, 2008.
- Butler, B. J., and E. C. Leatherberry. 2004. America's family forest owners. *J. For.* 102(7): 4-14.
- Cook, J. E., T. L. Sharik, and D. Wm. Smith. 1998. Oak regeneration in the Southern Appalachian. Potential problems and possible solutions. *South. J.App. For.* 22(1):11-18.
- Day Jr. F. P., and C. D. Monk. 1977. Net primary productivity and phenology on a southern Appalachian watershed. *Amer. J. Biol.* 64(9):1117-1125.
- Davis, L. R., K. J. Puettmann, and G. F. Tucker. 2007. Overstory response to alternative thinning treatments in young douglas-fir forests of western Oregon. *Northwest Science*. 81(1):1-14.
- Gottschalk, K. W., and W. R. MacFarlane. 1993. Photographic guide to crown condition of oaks. Use for gypsy moth Silvicultural treatments. General Technical Report NE-168. USDA FS. Northeastern Forest Experimental Station. Northeastern Area State and Private Forestry. Appalachian Integrated Pest Management Program. 4p.
- Hahn, J. T., and M. H. Hansen. 1992. Cubic and board foot volume models for the Central States. *North. J. Appl. For.* 8(2):47-57.
- Hicks Jr., R. R. 1998. *Ecology and Management of Central Hardwood Forests*. John Wiley and Sons, Inc., New York, NY, 412 p.
- Hill, E. J. 2000. Plant guide. USDA, NRCS National Plant Data Center and the Biota of North America program. Available online: [http://plants.usda.gov/plantguide/pdf/pg\\_quel.pdf](http://plants.usda.gov/plantguide/pdf/pg_quel.pdf). Last Accessed Sept, 2008.
- Hilt, D. E. 1979. Diameter growth of upland oaks after thinning. USDA FS. Research Paper NE-437. Northeastern Forest Experiment Station. 12p.

- Jenkins, M. A., and S. G. Pallardy. 1995. The influence of drought on red oak group species growth and mortality in the Missouri Ozarks. *Can. J. For. Res.* 25(7):1119–1127.
- Johnson, J. E., G. W. Miller, J. E. Baumgras, and C. D. West. 1998. Assessment of residual stand quality and regeneration following shelterwood cutting in central Appalachian hardwoods. *North. J. App. For.* 15(4): 203-210.
- Johnson, P. S. 1977. Predicting oak stump sprouting and sprout development in the Missouri Ozarks. USDA FS. North Central Forest Experiment Station, Res. Pap. NC-149. 11p.
- Johnson, P. S. 1994. The silviculture of northern red oak. P. 33-68 in *biology and silviculture of northern red oak in the north central region: A synopsis*, Isebrands, J.G., and R.E. Dickson (comps). USDA FS. North Central Forest Experiment Station. Gen. Tech. Rep. NC-173. 68p.
- Johnson, P. S. 2004. Thinking about oak forest as responsive ecosystems. P. 13-18 in: Spetich, Martin A., ed. 2004. *Upland oak ecology symposium: history, current conditions, and sustainability*. Gen. Tech. Rep. SRS-73. Asheville, NC: USDA FS Southern Research Station. 311 p.
- Kabrick, J. M., S. R. Shifley, R. G. Jensen, Z., Fan, and D. R. Larsen. 2004. Factors associated with oak mortality in Missouri Ozark forests. P. 27-35 in: Yaussy, D.A., Hix, D.M., Long, R.P., Goebel, P.C. (Eds.). *Proceedings of the 14<sup>th</sup> Central Hardwood Forest Conference*. USDA FS. General Technical Report NE-316.
- Kotar, J. 1997. Approaches to ecological based forest management on private lands. St. Paul Field office US State and Private Forest. Northeastern Area, State and Private Forest. 18p.
- Kotar, J., J. A. Kovach, and G. J. Brand. 1999. Analysis of the 1996 Wisconsin forest statistics by habitat type. St. Paul, MN. USDA FS. North Central Forest Experiment Station. Gen. Tech. Rep. NC-207. 165p.
- Keane, R. E., K. L. Gray, and L. J. Dickinson. 2007. Whitebark pine diameter growth response to removal of competition. USDA FS. Rocky Mountain Research Station. Research Note. RMRS-RN-32.
- Kuehl, R. O. 2000. *Designs of experiments. Statistical principles of research design and analysis*. 2<sup>nd</sup> ed. Pacific Grove. CA. USA. 666p.
- Kuuluvainen, J., H. Karppinen and V. Ovaskainen. Landowner objectives and nonindustrial private timber supply. *For. Science.* 42(3): 300-309

- Leuschner, W. A. 1984. Introduction to forest resource management. John Wiley sons. New York. 298p.
- Lynch, A. M., and J. R. Bassett. 1987. Oak stump sprouting on dry sites in Northern Lower Michigan. *North. J. App. For.* 4( ): 142-145.
- McGee, C. E. 1981. Response of overtopped oak to release. USDA FS. Southern Forest Research Station. SO-273. 3p.
- McGee, C. E., and D. E. Bivens. 1984. A billion overtopped white oaks: Assets or liabilities. *South. J. Appl. For.* 8: 216-220.
- Miller, G. W., J. N. Kochenderfer, and D. B. Fekedulegn. 2006. Influence of individual trees on nearby reproduction in two-aged Appalachian hardwood stands. *For. Eco. and Management.* 224(3): 241-251.
- Muir, P. S., R. L. Mattingly, J. C. Tappeiner, J. D. Bailey, W. E. Elliott, J. C. Hagar, J. C. Miller, E. B. Peterson, and E. E. Starkey. 2002. Managing for biodiversity in young Douglas-fir forests of western Oregon. USDI U.S. Geological Survey Biological Science Report. USGS/BRD/BSR-2002-0006:76. Forest and Rangeland Ecosystem Science Center, Corvallis, Oregon.
- Nichols, J.O. 1968. Oak mortality in Pennsylvania: a ten year study. *J. For.* 66(9): 681-694.
- Nielsen, C., and S.A. Bergman. 2004. The managed forest law property tax program. *Forestry Fact No.50.* University of Wisconsin Extension Service. Madison, WI.
- NOAA/National Climate Data Center. 2008. Central Wisconsin Palmer Drought Severity Index. Source: NOAA Satellite and Information Service. National Environmental Satellite, Data, and Information Service (NESDIS). National Climate Data Center. <http://www.aos.wisc.edu/~sco/clim-watch/graphics/pdsi-ts-05-l.gif> and <http://www.ncdc.noaa.gov/oa/climate/research/prelim/drought/zimage.html>. Last accessed February, 2008.
- Pregitzer, K. S., and C. W. Ramm. 1984. Classification of forest ecosystems in Michigan. In: Bockheim, J. G., ed. *Forest land classification: experiences, problems, perspectives: Proceedings of a symposium; 1984 March 18-20; Madison, WI.* Madison, WI: University of Wisconsin, Department of Soil Science: 114-131.
- Rogers R. 1990. *Quercus alba* L. White oak. In: R. M. Burns and B. H. Honkala (eds). *Silvics of North America. Vol. 2. Hardwoods. Agric. Handb. 654.* Washington, DC: USDA. FS. 744-750.
- Sander, I. L. 1977. *Manager's handbook for oaks in the north central states.* USDA FS. Gen. Tech. Rep. NC-37. North. Central. For. Exp. Station. St. Paul. MN. 35p

- Sander, I. L., and F. B. Clark. 1971. Reproduction of upland hardwood forests in the Central States. USDA FS. Agriculture handbook no. 405. 25p.
- Sander, I. L., P. S. Johnson, and R. F. Watt. 1976. A guide for evaluating the adequacy of oak advance reproduction. General Technical Report NC-23. USDA FS. North Central Forest Experimental Station. St. Paul. MN. 7p.
- Sander, I. L., P. S. Johnson, and R. Rogers. 1984. Evaluating oak advance reproduction in the Missouri Ozarks. USDA FS. Res. Pap. NC-251. 16p.
- Shifley, S. R., and W. B. Smith. 1982. Diameter growth, survival and volume estimates for Missouri trees. USDA FS. North Central Experiment Station. Res. Note. NC-292. 6p.
- Shifley, S. R., Z. Fan, J. M. Kabrick, and R. G. Jensen. 2006. Oak mortality risk factors and mortality estimation. *For. Ecol. Management.* 229: 16-26.
- Smith, H. C. 1965. Effects of clearcut openings on quality of hardwood border trees. *J. For.* 69:933-7.
- Smith, H. C., and N. I. Lamson. 1977. Stand development 25 years after a 9 inch diameter limit first cutting in Appalachian hardwoods. USDA FS. Northeastern Forest Experiment Station. Res. Pap. NE-379. 4p.
- Starkey, D. A., and J. M. Guldin. 2004. Crown health of reserve hardwood trees following reproduction cutting in the Ouachita Mountains. USDA FS. South Research Station. Gen. Tech. Rep. SRS-74. 6p.
- Steiner, K. C., J. C. Finley, P. J. Gould, S. Fei and M. McDill. 2008. Oak regeneration guidelines for central Appalachians. *N. J. Appl. For.* 25(1): 5-16.
- Trimble, G. R., Jr., and W. W. Seegrift. 1973. Epicormic branching on hardwood trees bordering openings. USDA FS. Res. Pap. NE-261. 10p.
- Trimble, G. R., Jr. 1975. Summaries of some silvical characteristics of several Appalachian hardwood trees. USDA FS. Gen. Tech. Rep. NE-16. 5p.
- USDA Forest Service. 2006. Oak Decline. Available: <http://www.ncrs.fs.fed.us/4154/focus/decline/>. Last accessed Aug, 2008.
- Wargo, P. M., D. R. Houston, and L. A. LeMadeleine. 1983. Oak decline. Forest Insect and Disease Leaflet 165. USDA FS. Washington, DC. 8p.

WI DNR. 2006. Silviculture and forests aesthetics manual. Available:  
<http://www.dnr.state.wi.us/forestry/Publications/Handbooks/24315/24315.pdf>  
Last accessed June, 2008.

## CHAPTER 3

# NORTHERN PIN OAK STUMP SPROUTING FREQUENCY ON SCRUB OAK SITES OF CENTRAL WISCONSIN

## ABSTRACT

Stump sprouting of northern pin oak is one of the main components of regeneration in scrub oak sites in Central Wisconsin; however, limited research has been conducted that will allow prediction of the rates of stump sprouting. During the winter of 2006-2007, four sites in the Sandhill Meadow Valley Wildlife Management Area were cut. During the summer of 2007, the northern pin oak stumps remaining after harvest were assessed for stump sprouting. Rates of stump sprouting were quite high with 84.7% for all stumps sprouting. Generally, small diameter stumps sprouted at a higher rate than large diameter stumps; however, sprouting rates of even the largest stumps did not drop below 70%. With stump sprouting rates this high, true coppice regeneration of scrub oak site should be possible.

**Keywords:** *Quercus*, coppice, regeneration

## INTRODUCTION

On dry, nutrient-poor sites (scrub oak) in Central Wisconsin, northern pin oak (*Quercus ellipsoidalis*) is a common component of forest stands (Sander 1990). Northern pin oak can grow vigorously in dry, acidic, sandy soils (Curtis 1959; Abrams 1990; Sander 1990) and has the ability to maintain high photosynthetic rates during drought conditions (Abrams 1988, 1990). Indeed, it is the most drought tolerant of the red oak group (Abrams 1988). While adequate advanced regeneration is uncommon on high site index (SI) oak sites (Sander et al. 1976; Steiner et al. 2008), advanced regeneration of northern pin oak is usually acceptable and competitive on scrub oak sites (Sander and Clark 1971; Sander et al. 1976). Northern pin oak sprouted vigorously (Lynch and Bassett 1987) from cut stumps and damaged saplings in Michigan. The high sprouting frequency combined with adequate advanced regeneration usually allows these sites to regenerate back to northern pin oak (Sander et al. 1984).

The conventional prescription for scrub oak harvest is coppice with rotation age of 45 to 70 years (WI DNR 2006). This prescription takes advantage of northern pin oak's stump sprouting ability and competitive advantage on dry, nutrient-poor sites. Because the trees are both young and small when cut on such a short rotation, the stumps would be expected to sprout at a very high rate (Baughman and Jacobs 1992; Sander et al. 1984; Johnson 1977, 1994). Because northern pin oak is very intolerant to shade (Pregitzer and Ramm 1984; Abrams 1988), complete overstory release also puts it in a position of strong competitive advantage over white and bur oak. For these reasons, scrub oak is considered to be a "durable" cover type in Wisconsin (WI DNR 2006).

With the importance of sprouting in the regeneration of northern pin oak sites, it is surprising that few studies have addressed rates of stump sprouting of this species. We were only able to find one study in the Lake States region that focused on northern pin oak sprouting rates on dry, nutrient-poor sites. Lynch and Bassett (1987), working on dry sites in Michigan, reported that 77% of the northern pin oak stumps produced a vigorous sprout and sprouting was independent of stump diameter. If stump sprouting for northern pin oak is indeed independent of stump diameter, this would be an uncommon (but not undocumented) phenomenon. Wendel (1975) in the Appalachians found sprouting of northern red oak was not impacted by diameter for trees less than 80 years old. Sprouting of most oaks and other hardwoods has generally been found to be dependent on stump diameter (Roth and Hepting 1943; Sander et al. 1984; George and Fisher 1991; Weigel and Johnson 1998; Weigel and Peng 2002; Morrissey et al. 2008). The lack of studies of northern pin oak stump sprouting combined with the reported independence of stump diameter to sprouting frequency (a potentially novel trait) led us to initiate this project in Central Wisconsin.

The objectives of this study were to 1) determine the frequency of sprouting of northern pin oak and 2) correlate northern pin oak sprouting frequency to parent stump diameter for scrub oak sites in Central Wisconsin.

## METHODS AND SITE SELECTION

Four scrub oak sites within the state-managed Meadow Valley and Sandhill Wildlife Areas in Central Wisconsin were harvested during the winters of 2006-2007. The soils within these wildlife areas are generally very nutrient-poor Psammments with locally high water tables. During the summer of 2007, these sites were visited to assess northern pin oak stump sprouting.

Northern pin oak was the dominant species in all the sites. On each site, 103-104 stumps along transect lines were assessed for sprouting and outside bark stump diameter (in.) measured using wood calipers to a 10<sup>th</sup> inch precision. The species northern red, black or white oak were not included within this study. The remaining stumps were in total 360 northern pin oak stumps were assessed for the analysis.

Northern pin oak stump sprouting was analyzed by binary logistic regression with sprouting tested as a binary factor predicted by stump diameter (in.) using Minitab® 15 Statistical Software (Minitab Inc.). The probability of sprouting was predicted by use of the equation,

$$P(\mathbf{x}) = \frac{1}{1 + e^{-(\alpha+\beta\mathbf{x})}} , \quad (1)$$

Where  $P(\mathbf{X})$  is the probability that a stump of diameter  $x$  (in.) will sprout, and the variables  $\alpha$  and  $\beta$  in the model are coefficients estimated from the data.

One possible metric for testing the predictive ability of a model produced by a logistic regression is the odds ratio. An odds ratio (OR) is a ratio of two odds when two individuals or groups are being compared.

$$OR = \frac{odds_{(observed\ sprouting)}}{odds_{(logistic\ regression\ predicted\ sprouting)}} \quad (2)$$

In this application, the odds ratio was used to assess the association between observed sprouting and logistic regression predicted sprouting. The odds ratio is a measure of association directly estimated from a logistic model (Kleinbaum 1994). An odds ratio close to 1 implies a strong association between the observed and predicted sprouting, while an odds ratio close to 0 implies that the association is weak (Kleinbaum 1994).

To test if the logistic regression model fits the data at an acceptable level, the Hosmer and Lemeshow goodness of fit test was used (Hosmer and Lemeshow 1989), with tests performed at  $\alpha = 0.05$ . The null hypothesis for this test is that there is no difference between the actual/observed and logistic regression predicted stump sprouting and non-sprouting respectively. This test compares the observed (actual) stump sprouting and non-sprouting with the logistic regression predicted stump sprout and non-sprout frequencies after grouping them into deciles.

## RESULTS

The binary logistic regression model possessed an odds ratio of 0.88 when predicting sprouting from stump diameter (Table 4). The odds ratio of 0.88 shows a strong relationship of stump diameters and stump sprouting for northern pin oak, suggesting that logistic regression model is a good predictor of northern pin oak stump sprouting.

From the 360 northern pin oak stumps assessed, 305 had at least one vigorous sprout. This is an average sprouting percentage of 84.7%. The binary logistic regression indicated that sprouting is related to stump diameter ( $p$ -value  $< 0.0001$ ) with sprouting increasing as stump diameter decreased (Table 5).

The Hosmer and Lemeshow's goodness of fit test for the observed and expected northern pin oak stump sprouting and non-sprouting frequencies was not significant ( $p = 0.719$ ). This indicates that the observed sprouting and non-sprouting frequencies and the predicted sprouting and non-sprouting frequencies were not significantly different (Table 6).

Table 4: Estimated coefficients, standard error of estimated coefficients, p-values and 95% confidence intervals for the binary logistic regression model predicting the probability of northern pin oak sprouting from diameter (in.).

---

Variable	Coefficient	Std. Err.	p-value	Odds Ratio	95% CI for the odds ratio	
					Lower	Upper
$\alpha$	3.0135	0.3722	<0.0001			
$\beta$	-0.1283	0.0310	<0.0001	0.88	0.83	0.93

Table 5: Observed and predicted northern pin oak sprouting (%) for various parent stump diameter classes in scrub oak sites of central Wisconsin

<b>Diameter (in.)</b>	<b>No. of Stumps</b>	<b>Predicted sprouting (%)</b>	<b>Actual Sprouting (%)</b>
1-2	15	94.7	100
2-4	51	93.3	98.0
4-6	24	91.5	91.7
6-8	59	89.2	86.4
8-10	65	86.5	86.2
10-12	61	83.2	78.7
12-14	27	79.3	77.8
14-16	30	74.8	73.3
16-18	14	69.7	71.4
18 +	14	64.0	71.4

Table 6: Observed (Obs) and estimated expected (Exp) frequencies within each decile of sprouting defined by fitted value for sprout present and no sprout present as developed by the binary logistic regression software.

Deciles	Sprout = 1		Sprout = 0		Total
	Obs.	Exp.	Obs.	Exp.	
1	25	23.7	11	12.3	36
2	29	30.2	10	8.8	39
3	35	35.3	8	7.7	43
4	28	30.4	8	5.6	36
5	35	35.4	6	5.6	41
6	34	34.3	5	4.7	39
7	32	32.2	4	3.8	36
8	34	33.9	3	3.1	37
9	37	34.5	0	2.5	37
10	16	15.1	0	0.9	16

## DISCUSSION AND CONCLUSION

Stump sprouting is an important source of oak regeneration in scrub oak stands (Sander 1977; Jakes 1982; Lynch and Bassett 1987; Johnson 1992). Though northern pin oak is the predominant oak in scrub oak sites, there has been relatively little research on its stump sprouting in these conditions. Our data show that at least one vigorous sprout was produced by 84.7% of the northern pin oak stumps and sprouting decreases with increasing stump diameter. Small diameter stumps (less than 4 inches) had almost a 100% chance of producing a vigorous sprout. Even very large stumps sprouted at rates greater than 70%. This high propensity to stump sprout would put northern pin oak at a strong competitive advantage over black, white or bur oak (Sander 1977; Lynch and Bassett 1987) in these dry, nutrient-poor environments.

Northern pin oak stump sprouting was strongly related to stump diameter. While Lynch and Bassett (1987) reported no relationship between stump diameter and sprouting frequency for northern pin oak, we found a strongly significant relationship. This is not necessarily inconsistent, because their work covered a different range of conditions than ours. Few of Lynch and Bassett (1987) trees were older than 70 years. While we did not age our stumps, the ages of reserve trees within these sites ranged from 35 to 110 years, indicating an uneven-aged structure. Based on this age distribution, a significant percentage of our stumps probably are older than 70 years (likely at least 1/3). Wendel (1975) showed that diameter had limited impact on sprouting for northern red oak younger than 70 years. Lynch and Bassett (1987) also studied a much broader range of site indices. Only 38% of the 384 trees they studied were on site with sites index of 50 feet or less at 50 years. The WI DNR definition of scrub oak includes only sites with a

site index of 50 feet at 50 years or less. The combination of a broader range of site indexes and a younger overall stand condition could significantly affect the relationship of diameter to sprouting. The overall percentage of stump sprouting that they measured, 77%, is quite comparable to the percentage that we found, 84.7%.

Relatively little advanced regeneration would be needed to fully stock a harvested scrub oak site with greater than 80% stump sprouting from northern pin oak. From previous research, we have found advanced regeneration to meet the 59% level of stocking (based on 1/735 acre stocked quadrat assessment) suggested by the DNR for sites prior to oak harvest (WI DNR 2006). With this adequate advanced regeneration and high predicted rates of stump sprouting, these sites would be expected to revegetate to predominantly northern pin oak following harvest. The current prescription for scrub oak, which is coppice with rotation age of 45 to 70 years (WI DNR 2006), appears to be well devised to meet the regeneration requirements.

## LITERATURE CITED

- Abrams, M. D. 1988. Comparative water relations of three successional hardwood species in central Wisconsin. *Tree Physiology*. 4(3): 263-273.
- Abrams, M. D. 1990. Adaptations and responses to drought in *Quercus* species of North America. *Tree Physiology*. 7(1-4): 227-238.
- Baughman, M. J., and R. D. Jacobs. 1992. Oak regeneration. Available online: <http://www.extension.umn.edu/distribution/naturalresources/DD5936.html>. Last accessed Sept, 2008.
- Curtis, J. T. 1959. The vegetation of Wisconsin. Madison, WI: University of Wisconsin Press. 657p.
- George, D. W., and B. C. Fisher. 1991. The occurrence of oaks reproduction after clearcut harvesting on Hoosier National Forest. *N. J. Appl. For.* 8(4): 144-146.
- Hosmer, D.W., and S. Lemeshow. 1989. Applied logistic regression. John Wiley & Sons, Inc. New York. 307p.
- Jakes, P. J. 1982. Timber resources of Michigan's northern Lower Peninsula, 1980. USDA FS. Resour. Bull. NC-62. 120 p.
- Johnson, P. S. 1977. Predicting oak stump sprouting and sprout development in the Missouri Ozarks. USDA FS. North Central Forest Experiment Station, Res. Pap. NC-149. 11 p.
- Johnson, P. S. 1992. Sources of oak reproduction. In: Loftis, D. L. and McGee, C. E. (eds.) Symposium proceedings, Oak regeneration. Serious problems, practical solutions. USDA FS. Southeastern Experiment Station. Gen. Tech. Rep. SE-84. 20p.
- Johnson, P. S. 1994. The silviculture of northern red oak. P. 33-68 in *Biology and Silviculture of Northern Red oak in the North Central Region: A synopsis*, Isebrands, J.G., and R.E. Dickson (comps). USDA FS. North Central Forest Experiment Station. Gen. Tech. Rep. NC-173. 68p.
- Kleinbaum, D. G. 1994. Logistic regression, a self learning text. Springer-Varlag. New York. 282p.
- Lynch, A. M., and J. R. Bassett. 1987. Oak stump sprouting on dry sites in Northern Lower Michigan. *North. J. App. For.* 4(3): 142-145.

- Morrissey, R. C., D. F. Jacobs, J. R. Seifert, B. C. Fisher, and J. A. Kershaw. 2008. Competitive success of natural oak regeneration in clearcuts during the stem exclusion stage. *Can. J. For. Res.* 38(6): 1419-1430.
- Pregitzer, K. S., and C. W. Ramm. 1984. Classification of forest ecosystems in Michigan. In: Bockheim, J. G., ed. *Forest land classification: experiences, problems, perspectives: Proceedings of a symposium; 1984 March 18-20; Madison, WI.* Madison, WI: University of Wisconsin, Department of Soil Science: 114-131.
- Roth, E. R., and G. H. Hepting. 1943. Origin and development of oak stump sprouts as affecting their likelihood to decay. *J. For.* 41(1): 27-36.
- Sander, I. L. 1977. *Manager's handbook for oaks in the north central states.* USDA FS. North Central experiment Station. Gen. Tech. Rep. NC-37. 35p.
- Sander, I. L. 1990. *Quercus velutina* Lam. Black oak. In: R. M. Burns and B. H. Honkala (eds). *Silvics of North America. Vol. 2. Hardwoods.* Agric. Handb. 654. Washington, DC: USDA. FS. 744-750.
- Sander, I. L., and F. B. Clark. 1971. *Reproduction of upland hardwood forests in the Central States.* USD A FS. Agriculture handbook no. 405. 25p.
- Sander, I. L., P. S. Johnson, and R. F. Watt. 1976. *A guide for evaluating the adequacy of oak advance reproduction.* General Technical Report NC-23. USDA FS. North Central Forest Experimental Station. St. Paul. MN. 7p.
- Sander, I. L., P. S. Johnson, and R. Rogers. 1984. *Evaluating oak advance reproduction in the Missouri Ozarks.* USDA FS. Res. Pap. NC-251. 16p.
- Steiner, K. C., J. C. Finley, P. J. Gould, S. Fei, and M. McDill. 2008. *Oak regeneration guidelines for the central Appalachians.* *N. J. Appl. For.* 25(1): 5-16.
- Weigel, D. R., and P. S. Johnson. 1998. *Stump sprouting probabilities for southern Indiana oaks.* USDA For. Serv. North Central Research Station Tech. Brief NC-7. 6 p.
- Weigel, D. R. and C-Y. J. Peng. 2002. *Predicting stump sprouting and competitive success of five oak species in southern Indiana.* *Can. J. For. Res.* 32(4): 703-712.
- Wendel, G.W. 1975. *Stump sprouts growth and quality of several Appalachian hardwood species after cutting.* USDA For. Serv. Res. Pap. NE-329. 9p.
- WI DNR. 2006. *Silviculture and forests aesthetics manual.* Available: <http://www.dnr.state.wi.us/forestry/Publications/Handbooks/24315/24315.pdf> Last accessed June, 2008.

## CHAPTER 4

# CONCLUSION

## RESERVE TREES

The current management prescriptions for scrub oak as presented in the Wisconsin Silviculture and Forest Aesthetics Handbook are limited to coppice with reserve of up to 2 trees per acre or shelterwood cut for sites with SI greater than 55ft. at 50 years (WI DNR 2006). However, since landowners own land for many reasons other than timber production, many have been resistant to clearcutting their parcels as it conflicts with their other management goals of ownership. The WI DNR has been resistant to allowing large numbers of reserve trees on scrub oak sites enrolled in the MFL program based on the concerns that 1) this overstory will compromise regeneration of the dominant species on the sites, northern pin oak and 2) that the reserve trees will die on the site. Both of these do not meet the requirement of “sound silviculture” that are intrinsic to the MFL program.

The first concern will need to be a subject for other researchers. However, for the second point, from our research it appears that white oak makes an excellent reserve tree with improvement in periodic annual increment (an index of volume growth) and improvement of other health parameters. Northern pin oak by contrasts appears to make a poor reserve tree and is destined to slow mortality after release if held for a longer period. For landowners wishing to maintain reserve trees, white oak across a broad age range and initial live crown ratio range can serve as a quality reserve tree. Northern pin oak, while

still viable reserve trees, are much less desirable due to long-term health and accelerated mortality.

## **NORTHERN PIN OAK STUMP SPROUTING**

Northern pin oak, a major component of oaks in the scrub oak sites, sprouts vigorously even at large stump diameter. However, little research was available until this project to aid land managers in predicting rates of sprouting. Overall, we found northern pin oak sprouting frequency to be greater than 80%. For small diameter stumps, nearly 100% sprouting was found. Even for very large diameter stumps, sprouting was greater than 70%. On scrub oak sites dominated by northern pin oak, even with little or no advance regeneration, stump sprouts could be expected to regenerate the stand back to oak.

## LITERATURE CITED

- Burns, R. M., and B. H. Honkala (eds.). 1990. *Silvics of North America vol.2*. USDA. FS. Agric. Handb. 654. Washington. DC. Available online: [http://na.fs.fed.us/spfo/pubs/silvics\\_manual/volume\\_2/vol2\\_Table\\_of\\_contents.htm](http://na.fs.fed.us/spfo/pubs/silvics_manual/volume_2/vol2_Table_of_contents.htm)
- Butler, B. J., and E. C. Leatherberry. 2004. America's family forest owners. *J. For.* 102(7): 4-14.
- Johnson, P. S. 1975. Growth and structural development of red oak sprout clumps. *For. Sci.* 21(4): 413-417.
- Johnson, P. S. 1977. Predicting oak stump sprouting and sprout development in the Missouri Ozarks. USDA FS. North Central Forest Experiment Station, Res. Pap. NC-149. 11p.
- Kotar, J. 1997. Approaches to ecological based forest management on private lands. USDA FS. St. Paul. Northeastern Area, State and Private Forest. 18p.
- Kotar, J., J. A. Kovach, and G. J. Brand. 1999. Analysis of the 1996 Wisconsin forest statistics by habitat type. St. Paul, MN. USDA FS. North Central Forest Experiment Station. Gen. Tech. Rep. NC-207. 165p.
- Kuuluvainen, J., H. Karppinen and V. Ovaskainen. 1996. Landowner objectives and nonindustrial private timber supply. *For. Science.* 42(3): 300-309
- Lynch, A. M., and J. R. Bassett. 1987. Oak stump sprouting on dry sites in Northern Lower Michigan. *North. J. App. For.* 4(3): 142-145.
- Miller, G. W., J. N. Kochenderfer, and D. B. Fekedulegn. 2006. Influence of individual trees on nearby reproduction in two-aged Appalachian hardwood stands. *For. Eco. and Management.* 224(3): 241-251.
- Nielsen, C., and S.A. Bergman. 2004. The managed forest law property tax program. Forestry Fact No.50. University of Wisconsin Extension Service. Madison, WI.
- Roth, E. R., and G. H. Hepting. 1943. Origin and development of oak stump sprouts as affecting their likelihood to decay. *J. For.* 41(1): 27-36.
- Sander, I. L. 1977. Manager's handbook for oaks in the north central states. Gen. Tech. Rep. NC-37. USDA FS. North Central Forest Experimental Station: St. Paul, MN. 35p.

- Sander, I. L., P. S. Johnson, and R. F. Watt. 1976. A guide for evaluating the adequacy of oak advance reproduction. General Technical Report NC-23. USDA FS. North Central Forest Experimental Station. St. Paul. MN. 7p.
- Sander, I. L., P. S. Johnson, and R. Rogers. 1984. Evaluating oak advance reproduction in the Missouri Ozarks. USDA FS. Res. Pap. NC-251. 16p.
- Shifley, S. R., and W. B. Smith. 1982. Diameter growth, survival and volume estimates for Missouri trees. USDA F.S. North Central Experiment Station. Res. Note. NC-292.
- Starkey, D. A., and J. M. Guldin. 2004. Crown health of reserve hardwood trees following reproduction cutting in the Ouachita Mountains. USDA FS. South Research Station. Gen. Tech. Rep. SRS-74. 6p.
- USDA Forest Service, 2006. Oak decline. Available:  
<http://www.ncrs.fs.fed.us/4154/focus/decline/> . Last accessed Sept, 2008.
- Wendel, G. W. 1975. Stump sprouts growth and quality in several Appalachian hardwood species after clearcutting. USDA FS. Res. Pap. NE-329.
- WI DNR. 2006. Silviculture and forests aesthetics manual. Available:  
<http://www.dnr.state.wi.us/forestry/Publications/Handbooks/24315/24315.pdf>.  
Last accessed June, 2008.

APPENDIX 1: OVERSTORY SURVEY FORM FOR RESERVE TREES

Forest/Property:																	Sheet ____ of ____			
Location and Legal Description:																	Surveyor(s) & Date:			
Year Cut:							Species:													
Comments:																				
Tree number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Height (ft.)																				
DBH (in.)																				
Epicormic branching																				
Live Crown ratio																				
Tree Vigor																				

KEY:

Tree vigor by use of crown condition

G= 1. Good crown: Tree has healthy foliage, less than 25% dead branches, little or no epicormic sprouting, no evident of canker

F= 2. Fair crown: 25 to 49% of the branches are dead, foliage density, size and coloration are subnormal or some evident of epicormic branching, and

P= 3. Poor crown: ≥50% branches dead, foliage density, size and coloration are subnormal or heavy epicormic branching and obvious canker,

D= 4. No crown and tree is dead

Epicormic branching

M= 1. Main bole, first stick

S = 2. Main bole, second stick

H= 3. Higher than first two sticks

Live crown ratio classes

Class 1: 1 - 25% crown present

Class 2: 26 - 50% crown present

Class 3: 51 - 75% crown present

Class 4: 76 - 100% crown present