



Within-Stand Retention Guidance

Principal Authors:

Jim Bielecki (DNR-FRD), Jim Ferris (DNR-FRD), Keith Kintigh (DNR-WLD),
Mike Koss (DNR-WLD), Don Kuhr (DNR-FRD), Sherry MacKinnon (DNR-WLD),
Scott Throop (DNR-FRD), Larry Visser (DNR-WLD), Mike Walters (MSU)

Editors:

Ron Murray, Keith Kintigh, Mike Walters, Jim Ferris

Revisions:

Dan McNamee (DNR-FRD), Karen Rodock (DNR-FRD), Monica Joseph (DNR-WLD),
Bruce Barlow (DNR-WLD), David Neumann (DNR-FRD), Tim Greco (DNR-FRD),
Cheryl Nelson (DNR-FRD), Tom Haxby (DNR-FMD)

Editors:

Penney Melchoir (DNR-WLD), William O'Neill, Debbie Begalle, Jeff Stampfly, Bill Sterrett,
Steve Milford, Eric Thompson, Tom Haxby

MICHIGAN DEPARTMENT OF NATURAL RESOURCES MISSION STATEMENT

"The Michigan Department of Natural Resources is committed to the conservation, protection, management, use and enjoyment of the state's natural and cultural resources for current and future generations."

NATURAL RESOURCES COMMISSION STATEMENT

The Natural Resources Commission, as the governing body for the Michigan Department of Natural Resources, provides a strategic framework for the DNR to effectively manage your resources. The NRC holds monthly, public meetings throughout Michigan, working closely with its constituencies in establishing and improving Natural Resources and Environment management policy.

The Michigan Department of Natural Resources (DNR) provides equal opportunities for employment and access to Michigan's Natural Resources. Both state and federal laws prohibit discrimination on the basis of race, color, national origin, religion, disability, age, sex, height, weight or marital status under the U.S. Civil Rights Acts of 1964 as amended, 1976 MI PA 453, 1976 MI PA 220, Title V of the Rehabilitation Act of 1973 as amended, and the 1990 Americans with Disabilities Act, as amended.

If you believe that you have been discriminated against in any program, activity, or facility, or if you desire additional information, please write: Human Resources, Michigan Department of Natural Resources, PO Box 30028, Lansing MI 48909-7528, or Michigan Department of Civil Rights, Cadillac Place, 3054 West Grand Blvd, Suite 3-600, Detroit, MI 48202, or Division of Federal Assistance, U.S. Fish and Wildlife Service, 4401 North Fairfax Drive, Mail Stop MBSP-4020, Arlington, VA 22203

For information or assistance on this publication, contact Forest Resource Management Section, Forest Resources Division, Michigan Department of Natural Resources, PO Box 30452, Lansing MI 48909-7952. This publication is available in alternative formats upon request.

Preface and Acknowledgements

Background. In 2006, the Michigan Department of Natural Resources (DNR) developed Within-Stand Retention Guidance (Bielecki et. al. 2006) as part of the certification program for the sustainable management of State Forest Lands. In 2011, after several years of using the guidelines, issues came to light, along with the Forest Stewardship Council (FSC) and Sustainable Forestry Initiative (SFI) revising their forest certification standards in 2010. An opportunity existed to further improve the guidelines while still providing a scientific, ecological basis for retention prescriptions, as well as practical field guidance.

This version of the guidance has been revised from the original to focus on clarifying some portions that were vague or subject to interpretation while making the guidelines easier to integrate into daily operations. This also incorporated the updated certification standards to meet the voluntary FSC and SFI certification standards which were both revised in 2010 and added requirements for retention of legacy trees and type 1 and type 2 old growth.

This Within-Stand Retention Guidance (Guidance) provides a general discussion of the ecological context of stand-level retention during silvicultural operations, including general guidance on features commonly considered for retention. This is followed by specific details for determining how much, what and where trees and snags should be retained. The last part of the Guidance consists of a series of sections describing each major cover type, associated sensitive features and other retention issues that should be considered when working in stands of these types.

The Guidance, while providing the background rationale for within-stand retention, also gives specific guidance for application to prescriptions. Managers are also given the option to deviate in specific instances with documentation, justification and approval through the compartment review process when the direction does not contribute to overall landscape management goals. This Guidance will be incorporated into the timber sale checklist and timber sale contract conditions. In general, all harvests including regeneration harvests will include prescriptions for retention.

Table of Contents

1. INTRODUCTION	1
2. PLANNING FRAMEWORK	1
3. ECOLOGICAL CONTEXT	1
A. AMOUNT TO BE RETAINED	3
4. TARGETED RETENTION CHARACTERISTICS	4
A. PREFERRED TREES FOR RETENTION	4
B. STAND STRUCTURE	4
C. TREE SPECIES DIVERSITY	5
D. MAST TREES	5
E. CAVITY TREES, STANDING DEAD, AND DOWNED WOOD	6
F. ADDITIONAL CONSIDERATIONS THAT INFLUENCE RETENTION	6
5. GENERAL RETENTION GUIDANCE	9
A. GENERAL RETENTION DOCUMENTATION	9
B. JUSTIFICATION FOR NO RETENTION	9
C. TYPE 1 AND TYPE 2 OLD GROWTH	10
D. LEGACY TREE	10
E. PRESCRIPTION EXAMPLES	11
6. SPECIFIC COVER TYPE RECOMMENDATIONS	12
A. NORTHERN HARDWOODS	12
B. OAK	13
C. PAPER BIRCH	15
D. ASPEN	16
E. HEMLOCK	17
F. WHITE PINE	18
G. RED PINE	20
H. JACK PINE	21
I. SPRUCE-FIR	23
J. LOWLAND CONIFERS	25
K. LOWLAND HARDWOODS	26
L. NORTHERN WHITE CEDAR	27
7. HOW TO CALCULATE THE AMOUNT OF RETENTION ACHIEVED	29
A. CALCULATING AREA-BASED RETENTION:	29
B. CALCULATING BASAL AREA-BASED RETENTION	32
8. REFERENCES AND LITERATURE CITED	34

List of Tables

Table 1. Amount to be Retained by Silvicultural System	3
Table 2. Est. % of Stand Area for the Ave. BA/Acre, DBH, & Crown Diameter of Trees Selected for Retention.	30
Table 3 Average Tree Crown Area	31
Table 4. Common Patch Sizes.....	32
Table 5. Number of Trees Per Acre Required to Meet Retention Goals of 3%, 5%, & 10%.	33

List of Figures

Figure 1. Distribution of Trees for Example 1, Method 1-Area Based Retention.....	31
---	----

1. INTRODUCTION

Purpose. Retention of live trees, snags, and down woody debris, which mimics natural disturbance regimes, is recognized as an important element in protection of soils, riparian areas, conservation of wildlife habitat and biodiversity, and is an indicator of sustainability in forest management. The purpose of this Within-Stand Retention Guidance for Michigan Forest Lands is four-fold:

- To provide guidance on live tree and snag retention that can be used during planning and implementation of harvests on state forests in Michigan.
- To provide a synthesis of current literature and research on the subject into practical field guidance on the scientific and ecological basis for retention prescriptions.
- To identify important ecological features about each major forest cover type, including sensitive plants, animals, and other features that are likely to occur within stands of these types.
- To conform to the standards for certification by the Forest Stewardship Council (FSC) and Sustainable Forestry Initiative (SFI).

2. PLANNING FRAMEWORK

Stand-level management decisions on public lands are increasingly made with consideration of larger landscape-level plans. Landscape-level planning activities consider the amount and arrangement of forest cover types, as well as site suitability for those cover types within the focus area. Based on site suitability, several different communities may be viable choices at a given site; however, some might be given higher priority for perpetuation or establishment given their ecological/biological, social, or economic values.

The guidance presented here is intended to address the important smaller stand level components of the landscape/eco-regional planning process. It is intended to be applied after consideration of landscape level issues using managerial discretion and sound professional judgment. In other words, after the decisions of “how much, where, when and how a cover type (community) will be managed” have been made. It is not intended to describe or guide decisions at the landscape level. This information should be viewed as guidance to help land managers determine which trees should be retained during harvest treatments.

Tools that may be available to aid decision making include: habitat-species models [e.g., MI WILD (Doepker et. al., 2001)], stream classification systems, Michigan’s Wildlife Action Plan (Eagle et. al. 2005), Michigan’s GAP Analysis, ecological classification systems (e.g., habitat types, Burger and Kotar 2003) and current and historical cover type distributions.

3. ECOLOGICAL CONTEXT

The purpose of this section is to establish the ecological rationale and framework for retention prescriptions. The information below is focused on characteristics of retention that are considered important for ecological and biological functionality, including wildlife habitat and biological diversity. Retention has other ecological values (e.g., carbon and nutrient retention), and social and economic impacts, but these are not addressed in this document. This Guidance may be revised in the future as new biological, ecological, social and economic information becomes available.

Retention decisions made at the stand level are critical because management of stands assembled together comprise communities. In turn, communities aggregated geographically comprise landscapes, and as such, their collective characteristics and distributions affect a multitude of ecological/biological, social and economic values over large geographic areas. Wildlife populations are impacted by stand structure, composition, size and spatial arrangement across the landscape. Harvest patterns consistent with the characteristic natural disturbance regime provide habitat at the smaller stand and aggregated at community and landscape levels.

Wildlife populations are impacted by forest stand structure and composition and the size and spatial arrangement of stands across the landscape. In general, wildlife abundance and diversity have been shown to correlate with structural and tree diversity within a stand (Menard et. al. 1982). For example, black-throated green warblers (BTGW) use mature northern hardwood stands containing a mature conifer component of about 15 to 20%. The conifer component must be present for the BTGW to settle in the stand and to be used as a breeding site. Another example is black-throated blue warblers (BTBW) which depend on mature forest conditions with well-developed shrub/sapling layers (Kearns et. al. 2006). However, it would be overly simplistic to prescribe maximum structural and compositional diversity for all stands. Kirtland's Warbler (KW), for example, is dependent on a horizontal structure of 200+ acre stands of young, dense jack pine trees, interspersed with small openings in compositionally simple jack pine forests (Probst and Weinrich 1993).

The habitat requirements for the greatest number of native wildlife species are provided by maintaining a broad representation of forest composition, structure, acreages and age classes across the landscape (Hunter 1990). Harvesting patterns mimicking natural disturbance patterns may provide habitat for the greatest number of species (Attiwill 1994). Such an approach is based on the assumption that species have adapted and evolved with the habitat conditions resulting from natural disturbances at the landscape level.

Targeting specific live and dead trees and patch characteristics for retention is a means for increasing structural and compositional diversity at the stand scale. Management specifications for retention should vary from cover type to cover type according to the established and emerging understanding of silviculture and disturbance dynamics (see specific suggestions for cover types in later sections), and also from site to site within cover types for the same reasons. Some stands could be prescribed less retention, and some more retention to mimic the historical variation in structural and compositional diversity in the landscape that result from natural disturbance. For example, some jack pine stands managed for KW could be prescribed lower retention levels to mimic structural and compositional diversity typical of stands originating from wildfire.

Retention characteristics should focus on maintaining important ecological functions and processes served by within-stand vegetation on each site, as expressed through wildlife habitat and biodiversity concerns. These include tree species diversity, mast trees, structural diversity, cavity trees, legacy trees, micro-habitats, and standing and downed coarse and fine dead wood.

A. Amount to be Retained

- 1) Forest managers should retain **3 to 10% of stand area** or 3 to 10% of the basal area depending on silvicultural system (Table 1). This recommendation was based in part on consideration of the size of historical disturbance patterns, and similar recommendations by other organizations for the overall amount of green tree retention and retention of specific structural and compositional components (snags, mast species, coarse woody debris) (OMNR 1991, Flatebo et. al. 1999). Groves of legacy trees and Type 1 and Type 2 old growth can be credited for this retention purpose.

Forest managers should consider including within-stand retention in all harvests, especially regeneration harvests, unless a sound reason for “no retention” or less than 3% retention is identified. For example, the amount of live tree retention and its association with harvest systems used on State Forest lands is described in Table 1.

See page 11 for example prescriptions which include retention and an example prescription for no retention.

Table 1. Amount to be Retained by Silvicultural System

Retention Amount	Silvicultural System
No Retention ¹	Any silvicultural system.
3%-10% of the harvest area (acreage) in retention	Clearcut with Reserves, Shelterwood with Reserves, Seed Tree with Reserves.
3%-10% of the residual basal area. ²	Single Tree Selection, Group Selection, Thinning*
*Includes “Crown”, “Low”, and “Systematic” thinning treatments.	
¹ ‘No retention’ or less than 3% retention is an option that may be prescribed for use on State Forest lands, but must be justified and approved as with any prescription at compartment review.	
² Unharvested patches may contribute toward retention goals in uneven-aged systems.	

Note that in even-aged harvest systems retention is specified as area-based, and that retention in uneven-aged systems and intermediate thinnings retention is residual basal area-based. However, unharvested patches may contribute toward retention goals in uneven-aged systems.

- 2) Area-based retention has been recommended for most stands managed using even-aged management. This can be accomplished by leaving a patch, patches or individual trees or a combination of both.
 - a. Area retained is a less variable measure of retention value for wildlife than the number of stems per acre. Tree size can vary tremendously, and the ecological effects and values of live trees, snags and coarse woody debris (CWD) increase with their size. For example, seed production (Krannitz and Duralia 2004), size and density of cavities (Kearney 2006), and vertebrate usage of CWD increase with tree age.
 - b. Targets for the number of trees per acre with desirable wildlife characteristics can be easily imbedded in area-based retention provisions (e.g., 10% area retention can include 2 oaks per acre that serve as mast trees).
 - c. Area based retention guidelines should result in a greater tendency for forest managers to preserve patches rather than retaining individual stems/trees.

4. TARGETED RETENTION CHARACTERISTICS AND ELEMENTS

Retention provides opportunities to enhance stand characteristics considered important for a broad range of ecological values. In this section, some of these characteristics are described with an emphasis on their value to wildlife, and general guidance is provided on managing for these characteristics.

A. Preferred Trees for Retention

- 1) All snags that do not pose a safety risk.
- 2) Live trees in various patch sizes, with preference to the following elements where they exist:
 - Trees representative of the dominant species naturally found on the site.
 - Legacy trees, where present, are not harvested.
 - Under-represented species.
 - Conifer/deciduous diversity.
 - Mast trees > 10" DBH where feasible (Hickory, Oak, American Beech, Black Cherry, Basswood and Ironwood are preferred in descending order).
 - Large/super-canopy trees.
 - Live cavity trees >10" DBH (preferred) where feasible.

B. Stand Structure

Forest structure can be described as the distribution of a collection of structural attributes which include, among others, canopy cover, tree spacing, species, height, diameter, understory and deadwood (McElhinny et. al. 2005). The number of wildlife species using a stand or landscape may be influenced by their respective structural complexities, but few studies have examined these relationships (e.g. Tanabe et. al. 2001). Structure, and its complexity, i.e., diversity, can be divided into vertical and horizontal components.

Vertical Diversity. At its simplest, vertical structural diversity can be defined as the number of vertical strata (i.e. layers) in the stand. Examples of important and sometimes under-represented vertical structural features include coarse woody debris (see below), understory shrub and sapling layers, sub-canopy and mid-canopy layers, and large and/or super-canopy trees. The density of understory shrub and sapling layers are dependent on many factors, including species composition (Oliver and Larson 1996), silvicultural management practices, canopy openness, site fertility, and deer browse (Randall and Walters 2004). Maintaining or promoting these strata may be enhanced by increasing the size of openings in partial harvests, and protecting these layers from harvest damage. The representation of large trees in a stand can be increased by permanent designation as reserve trees or groups of trees and by extending rotation age. The development of large trees can be accelerated by canopy release thinning around target trees (Singer and Lorimer 1997).

Super-canopy trees are large diameter trees that emerge above the main canopy of the stand. These trees are used for nesting sites by raptors, and by black bear for refuge and bedding sites. Super-canopy trees can be of any species; however, red pine, white pine, and white spruce are more likely than other species to be super-canopy trees because of the greater height and longevity that they achieve compared to their associates.

Horizontal Structural Diversity. Can be enhanced by using a broader range of canopy opening sizes in stands managed using single tree selection. For example, use some group selection-size openings, as well as single tree removals. Retaining some of the residual trees in clumps or patches in stands managed using shelterwood, seed tree harvests or clearcuts with reserves.

C. Tree Species Diversity

The number of wildlife species using a stand is thought to be positively correlated with stand composition and structural diversity, including trees in the overstory (Ontario Ministry of Natural Resources, 1998). Maintenance or enhancement of tree diversity is a common stand-level goal. Where this is the case, managers should encourage a mix of species that are associated with site conditions, that are currently or were historically present and that can be manipulated to meet stand (i.e. successional) and landscape goals. General resources that can aid in this assessment include habitat types (Burger and Kotar, 2003) for species and successional tendency associations of the site, and pre-settlement forest cover maps which are available at the following web address: (<http://web4.msue.msu.edu/mnfi/data/veg1800.cfm>).

During development of forest management plans, it is recommended that management objectives for each stand provide targets for species diversity, in both the residual overstory and the future overstory. For stands to be managed using uneven-aged techniques, objectives for the understory composition and structure should also be provided.

It is often appropriate to promote tree species diversity by favoring under-represented species for retention. Under-represented species are defined as those that are ecologically appropriate for the site and/or have ecological values that are desirable to enhance.

Examples include:

- 1) Mast producing species.
- 2) Long-lived species in short rotation stands (e.g. white pine in aspen stands), and
- 3) Conifers in deciduous stands and vice versa.

Conifers in hardwood stands such as white pine, hemlock, and white spruce provide considerable value for wildlife. Conifer inclusions in these and other stand types serve as thermal cover and habitat for mammals including deer, pine marten, fisher, and black bear. Large, “super-canopy” trees can serve as nesting habitat for bald eagles, osprey, and several other raptors.

D. Mast Trees

In Michigan, approximately 15% (55 species) of all terrestrial vertebrate wildlife species are associated with mast (MIWildHab (Doepker et. al., 2001)). These species rely on mast during peak production periods in late summer and early fall. High levels of fat, protein and carbohydrates in mast contribute to energy stores critical for migration, hibernation, and/or survival of young (Schnurr et. al. 2002). Mast species, in descending order of importance, are: hickory, oak, American beech, black cherry, basswood, and ironwood (OMNR 1998). Preferred mast trees are at least 10 inches dbh, with large, vigorous crowns. When selecting beech trees for retention, evidence of bear claw marks on the bark may indicate a consistent mast producer. In addition to trees, there are many mast producing shrubs,

including *Viburnum*, *Amelanchier*, hazelnut, and cherries. Harvest damage to these shrubs should be minimized where possible.

E. Cavity Trees, Standing Dead, and Downed Wood

Compared to unharvested forests, forests with a history of logging generally have lower densities of live cavity trees (Goodburn and Lorimer 1998), snags (Newbery 2006) and downed woody debris (Goodburn and Lorimer, 1998, Angers et. al. 2005). The presence of these characteristics is important for several species (Haartman 1957, Thomas et. al. 1976, Thomas et. al. 1979a, Dickson et. al. 1983). However, specific relationships between the density of these features and the presence/absence of dependent species are generally unknown. Coarse woody debris in the form of downed trees has a positive and significant effect on habitat availability in streams and lakes, and helps provide increased productive capacity for fish and aquatic invertebrates (Naiman and Latterell, 2005). However, the presence of downed trees and woody debris in water also has a dramatic effect on riparian habitat quality (Gregory et. al. 2003). Management activities in forested systems can have a negative effect on the supply of habitat for cavity users because: a) dead trees may be felled to comply with safety regulations, and b) declining trees may be preferentially removed to ease harvesting activities and meet timber production objectives of accelerating growth. The Ontario Ministry of Natural Resources (OMNR, 2001, 2004) recommends the following for densities of living cavity trees and snags for wildlife: retain at least 3 living cavity trees per acre, and up to 10 per acre as a combination of living cavity trees and dead and dying snags. Leaving a range of diameter classes (generally, larger is better) and a variety of tree species is preferable.

In managed stands, where the amount of Downed Woody Debris (DWD) is thought to be significantly lower than in unmanaged stands, several strategies could be used to increase DWD. They include: 1) encourage operators to leave unmerchantable portions of tree boles at harvest sites to provide large diameter DWD; 2) leave the tops of harvested trees distributed through the stand and not windrowed or piled at roadsides; 3) if DWD is lacking, consider girdling or felling and leaving unmerchantable stems. In addition, the DWD of hemlock and cedar, and perhaps other conifers, persists 2 to 3 times longer than hardwood DWD (Mattson et. al. 1987, Marx 2006). Although the felling or girdling of conifers may be undesirable, their retention as live trees may be desirable for many reasons, including their eventual death and contribution to DWD; 4) consider reducing or eliminating firewood permits in areas with low DWD. Firewood collecting reduces both the amount of DWD and possibly the number of snags; 5) when considering prescribed burns, burn when the moisture content of DWD is high. This will help to preserve DWD integrity; 6) in stands where heavy mortality has occurred, design salvage cuts to leave some dead standing and downed wood. This is most important in large acreage salvage cuts.

F. Additional Considerations that Influence Retention

Windfirmness. In addition, or at times, in opposition to the desired elements for live tree retention described above, windfirm trees or clumps of trees should be preferred for retention. Studies following the fate of retained trees in clearcuts found that a high percentage of retained trees uproot or snap in the first few years following harvest (Hautala et. al. 2004). In addition, logging damage to trees often introduces decay organisms that can cause trees to die from stem snap (Bebber et. al. 2005). Trees with cavities are desired for retention, but are particularly susceptible to snapping. These trees may be partially protected from snapping by reserving them in clumps of other trees. In general, super-

canopy trees are windfirm because their crowns have been exposed to high winds for a long time. Trees that have particularly poor windfirmness are those growing in areas with elevated water tables (since their roots are shallow) and those of co-dominant or lesser canopy positions that developed in high density even aged stands. These trees have not been exposed to high winds, and the high height to diameter ratios they developed under these crowded conditions make them more vulnerable to high winds (Scott and Mitchell 2005). For site and stand conditions with a high susceptibility for windthrow, consider higher stocking levels for post harvest retention. For example, retention of greater than 20% has been recommended in highly susceptible conditions (Scott and Mitchell 2005).

Retention Dynamics. Trees and tree patches retained after harvest are dynamic such that many of the targeted attributes contained in retention also change. For example, the number of live tree cavities could change over time, as some trees with cavities die and others develop cavities as they get older. In planning retention, care should be given to provide for target characteristics through at least the end of the next rotation (Stone et. al. 2002). For selection harvest systems, this planning may be relatively simple given the short harvest return interval. However, in clearcut systems with rotation lengths frequently in excess of 40 years, planning will be more complex and could include the retention of trees or clumps of trees expected to develop target characteristics over time, in addition to those trees or patches that currently exist.

Additional protection for retained trees in clearcuts could be provided by identifying trees with desirable wildlife characteristics, and then laying out retention such that the targeted stems occur in the middle of retained patches to increase protection from wind and/or exposure. Tying retention patches into other no-harvest, or limited harvest areas (such as riparian zones) could further increase patch protection.

Forest Health. Some species that could be used for retention have health issues which must be carefully considered. For example, residual red pine can harbor *Diplodia* shoot tip blight which will infect red pine seedlings, and may inhibit a goal to produce multi-storied red pine stand. Several other species have insect/disease problems [e.g., beech (beech bark disease), oak (oak wilt), jack pine (jack pine budworm), and ash (Emerald Ash Borer)] that could limit their use as retained green trees in some areas. Specific forest health information can be found on the DNR's Forest Health website. http://www.michigan.gov/dnr/0,1607,7-153-30301_30505_30830---,00.html for specific pests and other sources. This site should be consulted before prescribing retention of species that merit forest health considerations.

Sensitive Areas. Relatively rare and valuable habitats need protection. Some of these, such as oak barrens, savannas and dolomitic boulders, are treated in the cover types that they occur in (In "Cover Type Specific Considerations" below).

Vernal pools, intermittent streams, and seeps require special consideration, as they occur as small inclusions in many cover types. Where these occur, follow the soil and riparian area protection guidance in the MDEQ/MDNR Sustainable Soil And Water Quality Practices On Forest Land – IC4011. See the specific recommendations for protecting these features in the General Guidance section.

General Wildlife Considerations. Many wildlife species, especially those that are uncommon, should benefit from general habitat conditions created by the retention elements described above. However, some species may still need protection for critical site-specific

habitats such as nest sites for northern goshawk and red-shouldered hawk. Providing for a sustainable supply of suitable habitat per management guidance for these and other species may be critical to maintaining their presence. Other examples include:

Some nesting woodland raptors use mature, forked hardwoods to build heavy stick nests. Other raptors need mature conifers within hardwood stands for nesting. Eagle and osprey will use super-canopy white and red pine. Bald Eagles (currently listed as a species of special concern) may be nesting in super-canopy white pine in northern hardwood stands. Where bald eagles are nesting, the National Bald Eagle Management Guidelines (USFWS 2007) should be followed by retaining super canopy trees.

Young, regenerating stands can provide food and cover for many wildlife species, including ruffed grouse, snowshoe hare, and Chestnut-sided Warbler. Habitat can be improved for these wildlife species, if residual trees are retained for singing/song perches, hunting and hawking trees, and slash and/or downed logs are retained after harvest.

Sites with a dominant low-bush blueberry ground layer can be important feeding locations for black bears, white footed deer mice and other soft mast foragers in good fruit years.

In landscapes lacking a significant lowland conifer component, upland conifers may serve as important winter thermal cover for wildlife species, including white-tailed deer. Managers should identify such landscapes and consider management impacts on total available thermal cover. Conifer retention is important for some songbirds. The abundance and diversity of songbirds declines in northern hardwood stands with less than 4 conifer trees per acre (DeGraff 1987).

Black bear commonly leave their cubs at mature large white pine trees while they forage nearby in non-pine forest communities. Mature white pines have thick, fissured bark that escaping cubs can easily climb, and super-canopy trees of at least 20 inches in DBH are preferred. Trees that have bite marks, claw marks and show signs of disturbance at the base are trees that sows may be using year after year (Rogers and Lindquist 1992).

For ruffed grouse, retain one potential drumming log per acre that is at least 12 inches in diameter, and 4 to 10 feet long.

For rabbits and hares, create slash piles every 50 to 100 feet.

For conifer-nesting songbirds, maintain or promote development of 4 or more large (≥ 16 " DBH) conifers per acre, with a preference for trees with high vigor and low risk (OMNR 1998).

General Aquatic Resource Considerations. In riparian areas, retention of living and dead trees is usually desirable because they provide shade, contribute organic matter to aquatic food webs, and are a source of large woody debris (Benke and Wallace 2003, Boyer et. al. 2003, Dolloff and Warren 2003). Retained trees should be within one tree length of the stream for recruitment of large woody debris in the stream. Highly branched species and super-canopy trees will provide the greatest habitat benefits. Species such as hemlock, white pine and cedar will generally last longer in aquatic habitats than other tree species. Stand management activities in riparian areas should be consistent with the MDEQ/MDNR Sustainable Soil And Water Quality Practices On Forest Land – IC4011.

General Aesthetic Considerations. Vegetation groves for aesthetics can be considered as retention.

Specific Cover Type Recommendations (see pages 12-29).

5. GENERAL GUIDANCE

The guidance below will be incorporated into the timber sale checklist and timber sale contract specifications. Implementation will be evaluated as part of the general forest management review process.

A. General Retention Documentation

- 1) Retained trees or retention patches are intended to be left un-harvested until at least the next cutting cycle or rotation. In partial cut situations this will usually be the next harvest entry, which is typically 10 to 20 years in northern hardwoods. For clearcuts, this will normally be until the next rotation of the new stand, which is 40 years or longer for most cover types. Retention in intermediate harvests such as seed tree or shelterwood harvests should be retained until the next rotation of the new stand.
- 2) If there are sequential harvests in a parent stand, you have two options: 1) leave retention of an adequate size for the entire parent stand. You must identify and track this retention and it must be maintained throughout the rotation of the parent stand, or 2) leave retention in each treatment area.
- 3) Stand-level decisions on retention should be site specific and recommended by the stand examiner and wildlife biologist. Their decisions should comply with this Guidance and information specific to individual cover types in the sections that follow.
- 4) In addition, the fisheries biologist should be consulted in cases of harvest within stream corridors, where large woody debris can provide multiple habitat benefits.
- 5) All harvests with retention should be designated as such (e.g. clearcut with reserves); and in cases where it is justified, harvests that do not meet retention Guidance should be coded accordingly (e.g. Clearcut).
- 6) A description of the prescription for retention must be contained in the inventory notes section of the harvest prescription. This may contain all or a combination of the following information for retention: how much, what it is, general rationale for exceptions, location/distribution of larger patches, and special/unique features, if any. (See examples on page 11).

B. Justification for No Retention

“No Retention” or retention less than 3% is intended for those special cases where less retention is justified. These exceptions will be agreed upon at the Compartment Review for reasons including:

- **Forest Health**
- **Wildlife Requirements**

- **Small Stand Size or Narrow Width** (less than 10 acres and/or narrow stands that require full sunlight for regeneration)
- **Safety Issues**
- **Cover Type Conversion Concerns**
- **Silvicultural Rationale**

C. Type 1 and Type 2 Old Growth

Stands or areas of forest meeting the Type 1 or Type 2 old growth criteria (below and in Work Instruction 1.4) may be located during the inventory and/or sale preparation process. These areas may share some of the same characteristics with retention, e.g. snags, CWD, etc., and they may contribute to retention. However, they are tracked independently from retention. Detailed direction for type 1 and type 2 old growth encountered during inventory and/or sale preparation is as follows:

Old Growth forest (also termed primary forest, ancient forest, virgin forest, or primeval forest) is an area of forest that has few or no signs of human disturbance and that exhibits unique ecological features related to age, composition and associated structure. Old growth forests are of natural origin. They may be dominated by late successional forest species (i.e. sugar maple and American beech), or may be a very old example of a stand dominated by long-lived early- or mid-seral species (i.e. oak, or red pine). Actively or passively managed second growth forest stands (of natural or planted origin) which were effectively clearcut in the late 1800s and early 1900s, but have subsequently developed late-successional or old growth structure, composition, and function, are not considered to be Type 1 or Type 2 Old Growth.

Old Growth Stands and Forests Include:

Type 1 Old Growth: A forested area three acres or more in size that has never been logged and that display old-growth characteristics.

Type 2 Old Growth: A forested area 20 acres or more acres in size that has been logged (minor cutting), but which does not result in the elimination of any major canopy species and that retains (never lost) significant original elements of old-growth structure and functions.

D. Legacy Tree

An individual tree of a long-lived species, usually mature or remnant of old growth, which provides a biological legacy. It is an individual old tree (or occasionally a small group of old trees) that function(s) as a refuge or provides other important structural habitat values. By definition, relatively short-lived species (including big-tooth and trembling aspen, balsam fir, balsam poplar, and paper birch) cannot be legacy trees. Legacy trees must be 150+ years old or diameter at breast height is 26+ inches, and in either case will exhibit some of the following characteristics:

- Presence of hollows and cavities.
- Super-canopy crown position.
- Broken tops with crown debris accumulations and/or partial snag formation.
- Plate-like or thick fire-resistant bark.
- Fire scars and basal burn cavities.

An individual or group of legacy trees may contribute toward retention. However, they will not be tracked in the inventory.

E. Prescription Examples

Example 1. An aspen stand with minor overstory components of oak and red pine.

During the inventory stand examination, no red pine is recorded, but is observed in the stand. Oak is recorded as a minor component in the inventory. The stand is adjacent to a lowland conifer stand. The retention prescription at the time of inventory could be:

“Retain oak, red pine and a reserve strip of aspen along the transition to the lowland type as needed to achieve at least a 3% retention goal.”

While the precise amount of retention achieved with this prescription is not specified, the prescription is specific enough to meet the 3% area minimum required for State Forest lands. More detail should be added to the prescription when the timber sale is being prepared.

Example 2. A jack pine stand with occasional scattered white pine, red pine and white birch. Neither the white pine, red pine nor birch occurred in cruise points. The retention prescription could be:

”Retain all white pine, red pine and white birch. In addition, retain patches of jack pine as needed to meet minimum retention goals.”

Again, more detail should be added when the timber sale is prepared.

Example 3. An 80 acre aspen stand with a mixed component of oak and pine. The RX is for a final harvest and the Michigan Cross Country Cycle Trail (MCCCT) runs through the middle of the stand. You are about to attend a pre-inventory meeting and you have discussed the retention prescription with Wildlife Division, and they would like to see retention cover the low end of 3 -10%. You have not discussed the harvest with the Trails Analyst and you know you must address clearcutting the total length of the trail. The retention prescription could read:

“Leave retention in two approximately 2-acre islands along the MCCCT trail using the centerline of the trail as the midpoint of the retention islands. Focus retention islands on areas heavier to pine and oak.”

Example 4. You are inventorying a large northern hardwood stand and come across a 60 year old aspen stand with very irregular boundaries. You create the stand and the polygon is 10 acres in size. Your wildlife biologist would like to clearcut the stand and expand it into the hardwoods. Your prescription could read:

“Clearcut aspen stand and expand into the adjacent hardwoods. The total final harvest acreage should be approximately 15 acres. No retention due to small stand size and the need for full exposure to sunlight to stimulate aspen sprouting into adjacent hardwoods.”

6. SPECIFIC COVER TYPE RECOMMENDATIONS

A. NORTHERN HARDWOODS

1) Cover Type Characteristics:

Northern hardwood forests are a widespread, climax community of mesic, generally well drained uplands. Composition varies, but is generally dominated by sugar maple with minor associates including basswood, beech, white ash, red maple, bigtooth aspen and yellow birch, among others. Historically, the cover type burned much less frequently than other upland cover types and consequently, its disturbance regime was dominated by single treefall gaps and occasional extensive areas of windthrow (Frelich and Lorimer 1991). Silviculture has resulted in homogeneous sugar maple dominance on well drained sites and red maple in more poorly drained sites, at the expense of a decline in conifers (Zhang et. al. 2000). Prior to European settlement, the northern hardwoods cover type had a much larger white pine and hemlock component, with hemlock being especially prevalent in areas with finer textured soils and poorer drainage (Whitney 1986).

2) Retention Considerations:

Under-Represented Species. In northern hardwoods, under-represented species often include yellow birch, eastern hemlock, white pine, and black cherry. Efforts should be made to retain and encourage these under-represented species on a stand specific basis, especially larger individuals with high wildlife value and/or good form (the latter to serve as seed trees). Current Emerald Ash Borer and Beech Bark Disease Guidance should be consulted to inform decisions on retaining ash and American beech, respectively. In selecting individual trees for live tree retention, consider a mix of trees with longer lifespan and shorter lifespan. Sugar maple, yellow birch, hemlock, white pine, and northern red oak can live 200-300 years or more, whereas basswood, white ash, paper birch, and aspen rarely live more than 150 years. Retain and promote hemlock and white pine where they persist by maintaining and creating suitable sites for establishment through retention of nurse logs and exposure of mineral soil through prescribed surface fires or scarification. Where hemlock and pine local seed sources are absent, but where historical information and/or site conditions suggest these tree species were present, consider under-planting. Specific recommendations for conifer restoration are available for the Western Upper Peninsula (Herman et. al. 2004).

Mast Producers. The important hard mast producers in northern hardwood stands are American beech, and in more limited number of stands, northern red oak or hickory. Black cherry is the most important soft mast tree. Special effort should be made to retain oak and hickory where they occur because of the threat of beech bark disease to the beech hard mast resource.

Structure. Group selection thinning can be used to improve vertical and horizontal structural diversity, and may increase species diversity by encouraging growth of shade-intolerant and mid-tolerant species. Where snags and coarse woody debris are lacking, increase structural complexity by saving large diameter trees and allow them to die. Where intensive management for the purpose of increasing DWD is desired, girdling and felling of trees is an option. However, hemlock and white pine should not be girdled or felled, as they have greater retention values as live trees. If left, they will eventually

become part of the dead wood pool. White pine is the best super-canopy tree candidate in northern hardwood stands, although hemlock, white spruce and red pine can also attain greater heights than many of the broad-leaved deciduous species in northern hardwood forests (Fowells 1965).

Cavity Trees, Standing Dead, and Downed Wood. Where possible, a variety of tree species should be retained as cavity trees, snags and down logs. Cavity density is nearly twice as great on beech trees as other common northern hardwood species (Kearney 2006). However, complete reliance on beech to provide cavities may be unwise because of mortality anticipated in the future due to beech bark disease, and because wildlife use may vary among tree species with different characteristics (e.g. “softwood” species such as white pine and basswood, vs. “hardwood” sugar maple and beech).

3) Wildlife and Plants:

Several plants and animals of concern occur in northern hardwood forests. Plants include walking fern (State threatened), hart’s-tongue fern (State endangered), goblin moonwort (State threatened), and fairy bells (State endangered); and animals include red-shouldered hawk (State threatened), northern goshawk (State special concern), and several neo-tropical migratory warblers. Refer to Michigan Natural Features Inventory (MNFI) Community Abstracts (see MNFI website) and the DNR Wildlife Action Plan (Eagle et. al. 2005) for more complete lists of species of concern.

4) Rare Features/Communities:

Limestone or dolomitic boulders found in the Niagran escarpment of eastern Lake Michigan and northern Lake Huron shorelines are unique geologic features found in northern hardwood stands in these areas. They serve as micro-habitat for several rare plant species including Hart’s tongue fern, green spleenwort, and walking fern. Harvesting too close to the boulders can interrupt the canopy cover which may be required to maintain the micro-climate necessary for these plants. Where rare species have been identified, boulders should be protected in two ways: 1) protection from direct tree felling, and 2) protection from desiccation. To accomplish this, within 150 feet of these boulders, retain all conifers and a total BA of at least 100 square feet. In addition, no cutting should be done within 100 feet of the boulders. No trees should be felled directly onto the boulders.

B. OAK

1) Cover Type Characteristics:

Species composition in the oak cover type is predominantly red oak on more mesic sites, and some combination of black, white, red and/or northern pin oak on drier sites. The current broad distribution of mature oak dominated forests is the result of logging and fire history. The type occupies extensive areas that were once dominated by mixed white pine/red pine forests in which oaks were a subordinate species (Whitney 1987). The pines were harvested from these forests, and subsequent fires eliminated remaining pine and hardwood seed sources and favored oak sprouts as regeneration. Despite its current abundance, vigorous regeneration is poorly represented on all but the poorest

sites, and oak will eventually succeed to oak-pine mixes on poor sites, pine-red maple mixtures on intermediate sites, and sugar maple dominated hardwoods on mesic sites.

2) Retention Considerations:

Under-Represented Species: In oak stands on poor to intermediate sites (outwash and ice contact topography, respectively), white pine, and to a lesser extent, red pine, are relatively common components, with white pine especially common in the understory. The pines grow more vigorously than the oaks on these sites and prior to the logging era, they were generally the dominant tree species. In addition to silvicultural techniques aimed at encouraging pine in harvested areas, the pines could be further encouraged by including large “seed tree” pines as retention, and protecting larger regeneration in retention patches. On intermediate sites, maintaining oak as a component in future stands may hinge upon decreasing the density of the strong competitor red maple. If encouraging oak regeneration is a goal, then red maple should not be favored for retention. On mesic sites, harvesting oak will nearly insure that it becomes less important in the future stand, as its seedlings are strongly out-competed by seedlings of other hardwood species (Abrams 1998). Because of this, and the broad range of ecological values oak provides, some red oak should be retained, in addition to other desirable under-represented species sometimes found on these sites (e.g. hemlock, yellow birch, white pine).

Mast Producers. Oaks are excellent hard mast producers and should be retained in the stand, if possible. Black, pin and white oak on poor sites are not long-lived, and many stands in Michigan are 90-100 years old, which is old for these species. Where loss of vigor is evident or anticipated on dry sites, try to favor areas with oak regeneration for retention. Whether currently in the overstory or in the regeneration layer, favor oak species mixes on poor sites (e.g. black, red and white oak). This approach will increase the consistency of mast production among years, as different oak species can have large seed crops in different years. Amelanchier, cherry (black, pin, and choke), vaccinium and other soft mast producing species are also common on poor oak sites. On mesic oak sites, red oak and white oak can live >200 years. On these sites, red oak and beech are the most abundant high quality mast producers and beech is threatened by beech bark disease. For these reasons, oak should be favored for retention. Where a diversity of oak species exist in a particular stand or community, it is desirable to retain trees to promote the continuation of this diversity.

Structure. The oak cover type on poor to intermediate sites has a relatively open canopy that allows appreciable amounts of light to the forest floor. This, plus the relative abundance of intermediate shade tolerant species (e.g. amelanchier, white pine), can result in relatively complex vertical structure. Structural complexity can be enhanced by retaining white or red pine that is now in, or will reach, the super- canopy, and via partial harvesting to release understory shrubs and trees. White and red pines are the best super-canopy tree candidates on oak sites.

Cavities. On poor to intermediate oak sites, declining short lived oaks often have abundant cavities, as does aspen which is sometimes mixed with oak on the more mesic sites. However, the long-term persistence of these cavities cannot be relied upon. Preference could be given to white and red pine as cavity trees because they are likely to persist longer.

3) Wildlife and Plants:

Wildlife species of importance that are heavy users of mast in oak stands include white-tailed deer, black bear, wild turkeys, squirrels, ruffed grouse, jays, nuthatches and wood ducks (Martin et. al. 1951). Several plants and animals of concern may occur in oak forests or oak barrens. An example is the globally endangered Karner blue butterfly found in barrens communities. Other examples include silky aster, side-oats gamma grass, Great Plains spittlebug, and least shrew (all State threatened). Refer to MNFI Community Abstracts (see MNFI website) and the DNR Wildlife Action Plan (Eagle et. al. 2005) for more complete lists of species of concern.

4) Rare Features/Communities:

Savanna/Barrens Remnants. Open canopy oak stands, particularly those of fire origin or those presently maintained by fire, have the potential to contain rare barrens or savanna species. Oak-pine barrens contain rare plants, invertebrates, songbirds, mammals, and reptiles. Prescribed fire is the most important management tool to maintain and enhance these remnant communities. If the community is degraded by excessive canopy closure, selective cutting of canopy trees may be necessary prior to periodic prescribed fires. This selective cutting/retention practice for maintaining and restoring barrens and savanna communities can be considered retention under the Guidance. In cases where fire is to be reintroduced, large trees should be favored for retention, as they are the most fire resistant.

C. PAPER BIRCH

1) Cover Type Characteristics:

Paper birch is not a common cover type in Michigan's upland temperate forests. It reached its peak abundance in the canopy in the mid 20th Century, in response to the widespread fires that followed the logging era. Since the late 1980s, drought, pests and pathogens, and old age have reduced the amount of birch. Before European settlement, it was probably even less abundant than it is now, and was primarily found in poorly drained depressions. In these sites, it regenerated on elevated micro sites on coarse wood and tip up mounds. At present, it is found in several natural communities and associations including rich conifer swamp (usually a cedar cover type), boreal forest (spruce-fir), aspen and northern hardwood forest.

2) Retention Considerations:

Please see information on retention for the paper birch type in cedar, spruce-fir, and northern hardwood sections.

Mast Producers. There are few common hard mast species in this cover type. However, there may be several soft and hard mast shrubs and dwarf shrubs including *Corylus*, *Vaccinium*, *Rubus* and *Ribes*, that can benefit from harvesting disturbance in this type.

3) Species of Concern:

Since paper birch is relatively rare as a pure cover type and is commonly associated with other dominant types, plant and animal species typically find their habitat requirements in

the associated types such as rich conifer swamp (usually a cedar cover type), boreal forest (spruce-fir), aspen and northern hardwood forest. Several plants and animals of special concern occur in these communities including heart-leaved arnica (State endangered), purple clematis (State threatened), Canada rice-grass (State threatened), pine drops (State threatened), red-shouldered hawk, and northern goshawk. Refer to MNFI Community Abstracts and the DNR Wildlife Action Plan for more complete lists of species of concern.

D. ASPEN

1) Cover Type Characteristics:

Aspen is a common cover type and is found in all sites, except the extremes of acid peat soils and excessively drained outwash. Although the age class distribution on State lands in Michigan is skewed toward stands < 30 years old, there are some aspen stands older than the typical harvest age (i.e. > 50-70 years), where short-lived, early successional aspen is declining and stands are starting to succeed to other cover types. Common species in aspen understories vary as widely as aspen's distribution.

2) Retention Considerations:

Under-Represented Species: Aspen stands often are dominated by two aspen species; however, they may have species-rich tree and shrub understories that include: white pine, oaks, maples, beaked hazelnut, witch hazel, blueberry, honeysuckle and cherry. Aspen stands often provide good opportunities for maintaining and increasing tree and shrub diversity as one of the goals for retention, but there are few generalities given aspen's broad distribution. General recommendations are not very useful, except in red pine plantations, and assessment will have to be site specific. Decisions should be informed by habitat type, successional pathways, historic information, and species present. Given aspen's relatively short lifespan, retaining aspen trees and stand understory vegetation may result in the relatively rapid development of aspen snags, coarse wood, and a diverse understory.

Mast Producers. Oak and cherry are infrequently occurring mast-producing species that occur in aspen stands that should be retained.

Structure. Aspen stands are characterized by two major vertical structural strata, the canopy layer and a well developed understory. Opening up the understory via harvesting, and/or by overstory breakup due to mortality in older stands, will release advanced regeneration of other species and can stimulate aspen suckering. Leaving residual trees for singing/song/hunting perches can increase avian use of sawlog-size aspen stands. These layers, combined with retained, declining aspen trees and other longer lived species (maples, oaks, pines) will enhance vertical structure. As stands age, snag and coarse wood recruitment is often abundant, as a result of rapid self-thinning in aspen stands.

The vast majority of the stems that die naturally are small and may have limited wildlife value. Furthermore, because aspen decays quickly, the lifespan of both snags and DWD is short. Retention consisting of both shorter-lived aspen with longer-lived species may provide a steady supply of cavities, snags, and coarse wood for several decades.

Cavities. Kearney (2006) found that older aspen and birch had cavity densities that were higher than any other species, except American beech. However, aspen's value as a cavity tree is diminished somewhat by its relatively short lifespan (<100yrs).

3) Wildlife and Plants:

Important wildlife species that are dependant upon aspen are deer, elk, American woodcock, ruffed grouse, and beaver. Several plants of special concern occur in these communities such as heart-leaved arnica, fairy bells, and rayless mountain ragwort. Animal species of concern include red-shouldered hawk, and northern goshawk. Refer to MNFI Community Abstracts (see MNFI website) and the DNR Wildlife Action Plan (Eagle et. al. 2005) for more complete lists of species of concern.

E. HEMLOCK

1) Cover Type Characteristics:

Hemlock is a climax cover type and has the potential to be widespread on mesic, generally well drained to somewhat poorly drained uplands, and the finer textured soils of lake plains. It is also associated with ravines and the edges of swamps. Yellow birch, sugar maple and basswood are common associates. Historically, the cover type was most common on mesic and hydric upland sites that burned infrequently. The disturbance regime in hemlock stands was typified by gaps created from single tree fall and occasional larger windthrow disturbances (Frelich and Lorimer 1991).

2) Retention Considerations:

Under-Represented Species: Prior to European settlement, hemlock was much more widespread than it is currently (Whitney 1986). In areas where hemlock has declined, its common associate, yellow birch, has also declined sharply. In general, sugar maple has replaced hemlock on well drained sites, and red maple has replaced hemlock on more poorly drained sites (Zhang et. al. 2000). Because of hemlock's widespread decline and its high value for wildlife (see below), its presence as a cover type or as a minor associate in other types should be considered a notable ecological attribute. High priority should be given to preserve the hemlock that is left. Where hemlock and yellow birch occur as components of northern hardwood or lowland cover types, they should be favored for retention. Areas with hemlock seedlings and saplings should also be favored for retention.

Mast Producers. Few high quality mast producers are common in hemlock stands (e.g. beech), and where they occur, their retention may be of lower priority than retaining hemlock and its associate, yellow birch.

Structure. The structure of hemlock dominated stands may be relatively simple or complex, depending on stand history. Even-aged patches of hemlock, which are not uncommon in the upper Great Lakes region (Tyrell and Crow 1994), have relatively simple structure because their deep, and intermingled canopies allow less light to reach the forest floor than is needed to support understory vegetation. In mixed species stands, deep hemlock canopies add to the structural complexity. In old age stands, gap dynamics, hemlock's very high shade tolerance, and the slow decay rate of its dead

wood, contribute to vertical structural complexity of live trees and to standing and down dead wood (Marx 2005, Tyrell and Crow 2004).

Remnant, never harvested, hemlock-dominated stands exist, but are uncommon outside of Sylvania Wilderness Area, Porcupine Mountains State Park and the Huron Mountain Club. Stand examiners should assess hemlock-dominated stands, or portions of stands, for old age characteristics such as trees in many size classes, some very large trees, and large amounts of coarse woody debris and snags. Areas with these old age characteristics could be considered for reserve area status.

Cavities. Old hemlock and yellow birch attain large diameters and often have numerous cavities. Given their long lifespan, individuals of both species may provide cavities for a long period of time.

3) Wildlife and Plants:

Several plants and animals of concern occur in hemlock forests including walking fern (State threatened), hart's-tongue fern (State endangered), goblin moonwort (State threatened), fairy bells (State endangered), red-shouldered hawk (State threatened), and northern goshawk (State special concern). Refer to MNFI Community Abstracts (see MNFI website) and the DNR Wildlife Action Plan (Eagle et. al. 2005) for more complete lists of species of concern.

Many important wildlife species exhibit a preference for habitat found in hemlock forests, or in landscapes with a component of hemlock. Hemlock forest habitat contributes to maintaining viable populations of native wildlife. Birds associated with hemlock in Wisconsin include the Black-throated Green Warbler, Blackburnian Warbler, Winter Wren, Red-breasted Nuthatch, Solitary Vireo, Brown Creeper, Hermit Thrush, Northern Parula, and Yellow-rumped Warbler. Hemlock provides winter cover for white-tailed deer, ruffed grouse, and turkey. Mammals such as red squirrel and American marten, as well as a number of amphibians and reptiles, are associated with hemlock forests. In areas where lowland conifer stands are uncommon, upland hemlock stands may provide winter thermal cover for deer, moose, and other terrestrial species.

In addition, many bird species that depend on conifers, whether as the dominant cover type or as a minor component in hardwood stands, may have declined along with the representation of hemlock and other conifers that have occurred since the logging era (Drapeau et. al. 2000). Considering the benefits to wildlife from the hemlock cover type, enhancing hemlock in stands where it occurs, or could occur, should be a high priority.

F. WHITE PINE

1) Cover Type Characteristics:

Although it is a minor cover type in terms of acreage, the white pine cover type has had the fastest rate of acreage expansion of any State Forest cover type over the past 20 years, and it is a minor component in many cover types and across a broad range of habitat types (Burger and Kotar 2003). White pine may be more broadly distributed than any other species across gradients of fertility and hydrology; it is only excluded from the wettest sites. Where seed sources exist, it is now common in the understory of aspen

and oak cover types, many of these stands that were dominated by mixed red and white pine prior to the logging era.

2) Retention Considerations:

Under-Represented Species. White pine occupies a wide range of sites, but expresses dominance most commonly on wet hummocky areas and well drained upland sites. These areas are characterized by relatively diverse tree communities with associates including oak, red pine (upland only), aspen, hemlock, and red maple, and, in lowland areas, other conifer species. Given this high potential diversity and the large variability among stands, evaluation of under-represented species needs to be site specific. White pine's value as a retention tree comes from its long lifespan (up to 500 years), potential super-canopy height growth, long life as a snag or as DWD and other wildlife values (see below). Because of these characteristics, retention of white pine in all size classes should have high priority.

Structure. Except for dense, self thinning stands, white pine forests can have high vertical structural complexity because the canopies allow much light to reach lower strata. In the older stands, white pines can be present in all height classes including super-canopy trees, and several subordinate tree species can be present, including oaks and maples.

Mast Producers. In some parts of the State, the white pine cover type can have a large, multi-species oak component. Wherever opportunities exist, managers should enhance and perpetuate the oak component in white pine stands. These sites may be important mast producing areas for wildlife such as white-tailed deer and black bears. In other parts of the State, white pine has a large component of northern hardwoods. In these stands, the hard mast producing species including beech, black cherry, basswood, and ironwood should be retained.

Cavities. Large white pine, or other long-lived species in white pine stands, could provide a long-term cavity resource (see specifics below). These trees can be supplemented by shorter-lived species, such as aspen, that may develop cavities at a younger age.

3) Wildlife and Plants:

Important wildlife species that use white pine stands include black bear, fisher, and pine marten. Several plants and animals of special concern occur in white pine dominated communities including heart-leaved arnica (State endangered), purple clematis (State threatened), Canada rice-grass (State threatened), pine drops (State threatened), bald eagle (State threatened), and merlin (State threatened). Refer to MNFI Community Abstracts and the DNR Wildlife Action Plan for more complete lists of species of concern.

Specific features of white pine with value for wildlife include:

- a. Large, mature trees with broken tops provide habitat for cavity nesting wildlife.
- b. Black bears will make dens under the root mass of uprooted trees. Uprooted trees should be retained in these stands. These structures can be promoted by leaving trees to blow over after harvest or retaining trees in a salvage cut.

- c. Bark foraging bird species such as the brown creeper, pine warbler, white-breasted nuthatch, and red-breasted nuthatch search for insect prey in white pine's deep bark crenulations.
- d. Black bear sows commonly leave their cubs at mature white pine trees while foraging nearby in non-pine forest communities. These trees have thick, fissured bark that escaping cubs can easily climb. Super-canopy trees that are at least 20 inches DBH are preferred. Trees that have bite marks, claw marks and show signs of disturbance at the base are trees that sows may be using year after year (Rogers and Lindquist, 1992).
- e. Given its slow decomposition rates and large size, white pine has long residence time as a snag and as DWD.
- f. Trees infested with heart rot can be easily excavated by large woodpeckers.

G. RED PINE

1) Cover Type Characteristics:

In Michigan, red pine is a dominant or associate tree species in several natural communities. High quality natural communities containing red pine, including dry-mesic and dry northern forest, are among the rarest natural communities in the State. Before the logging era, mixed pine forests with red and white pine were a common cover type in areas now dominated by oaks, and red pine were found more frequently in forests and barrens now dominated by jack pine (Whitney 1986). In contrast to natural communities, there are over 950,000 acres of red pine plantations in Michigan. These plantations are distributed broadly, occurring on dry and dry-mesic sites where it occurred naturally, and on mesic sites. Many of the plantations are at, or nearing maturity, and provide the opportunity for leaving large residual red pine that could be used for several different retention goals (see below).

2) Retention Considerations:

Under-Represented Species: In the red pine cover type, red pine and white pine, a common associate, are good candidates for retention because of their longevity. Priorities for retention can be set by viewing mixed pine communities as being under-represented in the landscape and across State forests, instead of as a particular species. At final harvest, even-aged red pine plantations provide excellent opportunities for conversion to under-represented, multi-cohort red pine or mixed pine-oak communities on appropriate habitat types (see Burger and Kotar 2003). Careful planning for red pine retention on candidate sites and the possible re-introduction of fire would be critical elements of a restoration plan for these communities. Although red pine was not common on mesic sites, retention of some red pine at final harvest in plantation stands might provide some of the same values (e.g. super-canopy trees) as white pine or hemlock in the future hardwood stand. In general, live wood/legacy tree retention objectives can be met by leaving mature red pine as individual trees, clumps, or simulated fuel breaks. Determination of the appropriate live tree retention location should consider impacts on harvesting, regeneration, recreation and visual management.

Mast Producers. The red pine cover type can often have a large, multi-species oak component. These stands may be extremely important mast producing areas for wildlife such as white-tailed deer and black bears. Managers should enhance and perpetuate the oak component when present.

Structure. Except in dense, self-thinning stands, red pine stands can have high vertical structural complexity because the canopies allow much light to reach lower strata. In the older stands, red pine stands can include several subordinate tree species including oaks and red maple.

Cavities. Large diameter red pine, or other long-lived species in red pine stands (e.g. white pine), may provide a good long-term cavity resource (see specifics below). These trees can be supplemented by shorter-lived species, such as oaks and jack pine, that may develop cavities at a younger total age than pine and other long-lived species.

3) Wildlife and Plants:

Important wildlife species that use red pine stands include pine warblers, fisher and pine marten. Several plants and animals of special concern, in addition to the barrens plant species described below, occur in red pine forests. Refer to MNFI Community Abstracts (see MNFI website) and the DNR Wildlife Action Plan (Eagle et. al. 2005) for more complete lists of species of concern.

4) Rare Features/Communities:

As described above, high quality natural communities containing red pine, including dry-mesic and dry northern forest, are among the rarest natural communities in the State. Historically, these communities were maintained by frequent surface fires and infrequent crown fires. These communities should be identified and considered for active maintenance/restoration of community integrity.

Barrens/Prairie Remnants. Red pine stands, particularly those of fire origin, have the potential to contain barrens and prairie remnants. Prior to management, care should be taken to assess the potential for maintaining and enhancing barrens and prairie remnants. Diagnostic species abundant in high quality barrens and prairie remnants include big and little bluestem, pale agoseris, rough fescue, Hill's thistle, Canada rice grass, and Alleghany plum. In addition to fire, plant species associated with barrens/prairie remnants can be enhanced with silvicultural practices that disturb the forest floor and expose mineral soil. Areas that are currently high quality barrens and prairie remnants, or have the potential to be, should receive consideration for maintenance or restoration management practices that include careful consideration of retention characteristics and the reintroduction of a frequent fire regime.

H. JACK PINE

1) Cover Type Characteristics:

In Michigan, jack pine is a dominant or associate tree species in several natural communities. It is dominant in dry forests on the excessively well drained sands of outwash plains topography. These communities are the most fire prone in the State. Areas with jack pine are often mono-dominant, but common associates may include red pine, white pine, northern pin oak, and bigtooth aspen. Oak is an associate in areas with good cold air drainage, as it is susceptible to, and excluded from, areas with late season frosts.

2) Retention Considerations:

Under-Represented Species: Red and white pine are good candidates for retention because of their longevity, positive impacts on vertical structure, cavities and wildlife values (see below and elsewhere). Retaining old, large diameter jack pine is also important because older jack pine is generally under-represented in the jack pine cover type. In addition, they generally have much shorter lifespan than red pine, thus will produce snags more quickly, with snags typically persisting < 20 years following mortality. Leaving some wildfire burned areas unsalvaged will increase the representation of snags and DWD on the landscape. Consideration of forest health risks must be made when areas of fire killed pine are left untreated, due to the potential to create brood locations for various pine beetles that could endanger nearby healthy, unburned stands. For example, jack pine more than 50 years of age is highly susceptible to jack pine budworm infestations.

Mast Producers. Oaks are the only mast producers in jack pine stands. If the oak trees are healthy and vigorous, leave them as mast trees, favoring species mixtures where they exist. In some areas, northern pin oak or black oak may be the only mast tree options.

Structure. Jack pine stands have relatively simple vertical structure, as jack pine has a relatively short stature and shallow crown, and understories are often sparse. Retaining or promoting larger diameter and taller red pine, white pine and oak will increase vertical structure. Much of the jack pine area is clearcut harvested with a rotation of 50-60 years. Although this matches the average pre-settlement fire rotation, because fire was more of a chance event, and because fire susceptibility varied over the landscape, there were many areas without fire for much longer than 60 years, and there were areas that burned much more frequently than every 60 years (D. Cleland, unpublished data). The areas that burned less frequently would have had greater densities of snags and DWD from short-lived jack pine, oaks, and aspen, and large longer-lived red pine and white pine trees. Areas that burned very frequently might have developed barrens characteristics (see below).

Landscape (i.e. horizontal) structural complexity could be enhanced by more closely emulating the variation in disturbance frequency that typified these areas and not just the average fire rotation.

Furthermore, unlike clearcut areas, burned areas typically have undulating boundaries with peninsulas of unburned areas with live trees that jut into burned areas, as well as islands of live trees in the middle of burned areas (OMNR 2001). To more closely emulate natural disturbance, a pattern of island and peninsula shaped residual patches is advised. The general approach is as follows: a) retain islands of greater than 0.5 acre, and peninsular areas; b) island patches will be left as permanent retention. Peninsulas can be harvested when adjacent stands are harvested, if feasible; c) if harvesting of peninsulas is not feasible in future harvests, then peninsulas can be partially cut at the time of the original harvest, removing as much as 50% of the trees by group selection.

Cavities. Large red or white pine, if present, would provide the best long-term cavity resource (see specifics below). These trees can be supplemented by shorter-lived jack pine, aspen and oaks that may develop cavities at a younger total age than pine and other long-lived species.

3) Wildlife and Plants:

Approximately 90,000 acres of jack pine on State Forest land is designated as essential habitat for Kirtland's warbler (KW) management. For those stands in designated KW Management Areas, managers should refer to the Kirtland's Warbler Habitat Management Guidance.

As a general rule, jack pine stands managed for KWs should be at least 200 acres in size, but preferably 500 acres or greater. An ideal stand would contain a mosaic of highly stocked jack pine (1,600 trees/acre), over 75% of the area with the remaining 25% left unstocked. Historically, this mosaic has been achieved through planting in an opposing wave pattern.

Large KW treatments serve an important role for open and shrubland species during early stages of regeneration. These species include the eastern bluebird (if snags are present), white-tailed deer, wild turkey, American woodcock, upland sandpiper, and common nighthawk. Several plants and animals of special concern in addition to KW and the barrens plant species described below occur in jack pine forests. Some species are dependent on snags in jack pine stands; these include northern myotis, eastern bluebird, northern saw-whet owl, and black-backed woodpecker. Refer to MNFI Community Abstracts and the DNR Wildlife Action Plan for complete lists of species of concern.

4) Rare Features/Communities:

Jack pine stands, particularly those of fire origin, have the potential to contain barrens and prairie remnants. Prior to management, care should be taken to assess the potential for maintaining and enhancing barrens and prairie remnants. Diagnostic species abundant in high quality barrens and prairie remnants include big and little bluestem, pale agoseris, rough fescue, Hill's thistle, Canada rice grass, and Alleghany plum. In addition to fire, plant species associated with barrens/prairie remnants can be enhanced with silvicultural practices that disturb the forest floor and expose mineral soil. Areas that are currently high quality barrens and prairie remnants, or have the potential to be, should receive consideration for maintenance or restoration management practices that include the careful consideration of retention characteristics and the reintroduction of a frequent fire regime.

I. SPRUCE-FIR

1) Cover Type Characteristics:

The spruce-fir cover type is usually associated with boreal and sub-boreal forest communities, but can also be found in the dry-mesic and mesic sites in northern temperate regions. The cover type is later successional, often replacing jack pine, aspen and birch, as both white spruce and balsam fir are fire intolerant and more shade tolerant than the species they replace. Spruce-fir is not a common cover type in Michigan, but it may increase in this era of fire suppression especially on the more poorly drained pine sites.

2) Retention Considerations:

Under-Represented Species: Spruce are often less abundant than fir in the spruce-fir type. This is likely because the type is often late successional, with spruce regeneration disadvantaged by its lesser shade tolerance (Kneeshaw et. al. (2006) and more specific seedling establishment substrate requirements (Simard et. al. 2003). Thus, if the management goal is to increase spruce representation, then spruce could be considered under-represented. Spruce has greater maximum lifespan (300+ years) than fir (<150 years) (Newbery, et. al. 200X). In addition, balsam fir greater than 60 years of age is highly susceptible to spruce budworm infestations. For these reasons, windfirm (e.g. super-canopy) spruce should generally be favored over balsam fir for retention. However, high retention (>20 %) or conversion to uneven-aged management should be considered in this forest type because neither species is very windfirm, thus isolated retention patches blow over easily.

Mast Producers. There are few common hard mast species in this cover type. However, there may be several soft and hard mast shrubs and dwarf shrubs including *Corylus*, *Vaccinium*, *Rubus* and *Ribes*, that can benefit from partial harvesting.

Structure. Maintaining both spruce and fir components is important in these stands. Spruce have larger diameter and are taller than fir, resulting in forests that have a two-tiered structure or a multi-storied structure in old age stands (Newbery et. al. 2006). On wetter, or fire protected sites (e.g. leeward sides of bodies of water and islands), spruce-fir forests can persist long enough between large scale disturbances, that individual to multiple tree-fall gaps predominate (Newbery et. al. 2006). Extremely shade tolerant northern white cedar or hemlock can become components in these late stage forests, and paper birch can establish in some gaps on rotting logs (Frelich 2002). On drier sites, these forests may have more even-aged structure. These patterns can be emulated with harvest systems that match local conditions. Both fir and spruce have persistent snags that can stand 35+ years after mortality, and both have decay resistant DWD that can persist for 60+ years (Newbery et. al. 2004).

Cavities. In spruce-fir stands, spruce may be preferred for retention as cavity trees because of its larger size and greater longevity.

3) Wildlife and Plants:

Important wildlife species that use spruce-fir include moose, black bear, fisher, and bobcat. Where the spruce-fir type is within the influence zone of the Great Lakes, a variety of orchids are species of concern, as well as one raptor, the merlin. Referring to management guidance for these species may be critical to maintaining their presence. Other plants of special concern include squashberry, northern fairy bells, and small-flowered woodrush. Refer to MNFI Community Abstracts and the DNR Wildlife Action Plan for more complete lists of species of concern.

4) Rare Features/Communities:

Spruce-fir communities with late successional characteristics are relatively rare. Stand examiners should consider identifying spruce-fir communities with old age characteristics (some large trees, treefall gaps, and abundant snags and downed wood as potential reserve areas).

J. LOWLAND CONIFERS

1) Cover Type Characteristics:

The Lowland Conifer cover type includes a broad array of mixed conifer dominated forested wetland communities. Natural communities include poor conifer swamps, rich conifer swamps, relict conifer swamps, and hardwood-conifer swamps. Dominant tree species include balsam fir, cedar, tamarack, black and white spruce, and jack pine. Sites may also include, to a lesser extent, aspen, birch, cottonwood, balsam poplar, black and red ash, red and silver maple, elm, and swamp white oak.

2) Retention Considerations:

Forest Treatments in Lowlands. Treatments have been conducted in lowland conifer forested systems with varying success. Cuttings in these systems were common on State lands in the 1970s and 1980s, as part of a concerted effort to improve white-tailed deer range. Treatments did improve winter survivorship of deer and many sites produced successful regeneration. On many sites, however, multiple factors hindered regeneration, including: 1) alteration of evapo-transpiration potential causing surface water level to increase, and 2) excessive persistent deer browsing.

Because of the fragility of hydric soils, harvest treatments should be conducted in winter, with frozen ground conditions, as much as possible. Harvesting in these sensitive sites should be done using low ground pressure equipment with close attention given to the potential for rutting, soil compaction, root damage and disruption of sub-surface drainage. In areas with high winter deer densities, high levels of residual slash and tops may be necessary to limit deer access to regeneration to prevent over-browsing.

Under-Represented Species. Similar to many upland sites, treatments should attempt to protect under-represented conifer species particularly cedar, hemlock, and white pine. In systems where black ash occurs, current Emerald Ash Borer Guidance should be consulted to inform decision on retaining ash.

Mast Producers. Mast producing tree species are uncommon in lowland forest sites. However, canopy gaps can be important for mast producing shrubs, grasses and forbs. These plants, including skunk cabbage, are important sources of spring forage for black bears.

Structure. Often trees in lowland forested communities are subject to windthrow during severe storms, as they have shallow roots. This disturbance, along with lightning strikes, has the potential to create a structurally and compositionally complex forest of many age classes and tree species. In stands lacking these characteristics, vertical structure can be enhanced by retaining or promoting a broad array of species and size/age classes.

Cavities. Lowland forested communities with high levels of short-lived species like aspen and birch may have adequate levels of snags and coarse woody debris present. However, long-lived species within these systems may have not yet reached the age where cavities have developed. To accelerate this process, girdling and felling of some trees is an option. Cedar and tamarack downed wood may persist for long periods of time due to its decay resistance.

3) Wildlife and Plants:

At least 16 rare plants and 15 rare animal species are associated with these communities, including the following species of special concern: Ram's Head Orchid; Tamarack Tree Cricket; Eastern Massasauga; Blanding's turtle; Spruce Grouse; and Black-backed Woodpecker. One State-listed endangered species (Hine's Emerald Dragonfly) and six State-listed threatened species (Calypso Orchid; Limestone Oak Fern; Black Crowberry; Spotted Turtle; Long-eared Owl; and Red-shouldered Hawk) are associated with lowland conifer forests.

With the onset of winter, lowland conifer is a preferred habitat for resident wildlife species. During the winter months, snowshoe hare, bobcat, gray wolf, and white-tailed deer all intensify their use of lowland conifer forests, particularly northern white cedar. Northern white cedar is a preferred species in deeryards because it provides excellent protection from snow and wind, and is the only browse species that, by itself, will maintain deer over winter in good health. Dense, mature lowland conifer stands exhibit narrow thermal ranges, warmer average temperatures, low windflow, and diminished hazardous conditions. High quality deer wintering areas are characterized by having approximately 50% of the landscape in productive, mature or over-mature, well-stocked (100 square feet of basal area) coniferous stands. Shelter requirements for deer may vary considerably dependent on the magnitude of winter weather severity and the quality and quantity of food available.

K. LOWLAND HARDWOODS

1) Cover Type Characteristics:

The Lowland Hardwood cover type includes a broad array of deciduous dominated forested wetland communities. Natural communities include hardwood-conifer swamp, northern swamp, southern swamp, and southern floodplain forest. Dominant tree species include aspen, birch, cottonwood, balsam poplar, black and red ash, red and silver maple, elm, and swamp white oak. Sites may also include, to a lesser extent, northern white cedar, tamarack, balsam fir, and black and white spruce. These conifer species may have been more dominant on many of these sites historically. Lowland hardwoods are generally either swamps or floodplains that may be flooded in the spring and/or fall, often causing the ground layer to be relatively sparse. However, on some sites, tree density can be low which can result in a dense groundcover.

2) Retention Considerations:

Forest Treatments in Lowlands. Treatments have been conducted in lowland hardwood forested systems with varying success. Cuttings in these systems were common on State Forest lands in the 1970s and 1980s, as part of a concerted effort to improve white-tailed deer range. Treatments did improve winter survivorship of deer and many sites produced successful regeneration. However, on other sites, multiple factors hindered regeneration, including: 1) alteration of evapo-transpiration potential causing surface water level to increase, and 2) excessive persistent deer browsing.

Because of the fragility of hydric soils, harvest treatments should be conducted in winter, with frozen ground conditions, as much as possible. Harvesting in these sensitive sites should be done using low ground pressure equipment with close attention given to the potential for rutting, soil compaction, root damage and disruption of sub-surface drainage. In areas with high winter deer densities, high levels of residual slash and tops may be necessary to limit deer access to regeneration to prevent over-browsing.

Under-Represented Species. Many lowland hardwood systems were formerly dominated by conifer species. Similar to many upland sites, harvest treatments should attempt to protect under-represented conifer species particularly cedar, hemlock, and white pine. Where black ash occurs, current Emerald Ash Borer Guidance should be consulted to inform decision on retaining ash.

Mast Producers. Mast producing tree species are uncommon in lowland forest sites. However, canopy gaps can be important for mast producing shrubs, grasses and forbs. These plants, including skunk cabbage, are important sources of spring forage for black bears.

Structure. Often trees in lowland hardwood communities are subject to windthrow, as they have shallow roots. This disturbance, along with lightning strikes, has the potential to create a structurally and compositionally complex forest of many age classes and tree species. In stands lacking characteristics, vertical structure can be enhanced by retaining or promoting a broad array of species and size/age classes.

Cavities. Lowland forested communities with high levels of short-lived species like aspen and birch may have adequate levels of snags and coarse woody debris present. However, long-lived species within these systems may have not yet reached the age where cavities have developed. To accelerate this process, girdling and felling of some trees is an option. Cedar and tamarack downed wood may persist for long periods of time due to its decay resistance.

3) Wildlife and Plants:

Endangered, threatened or special concern species include: eastern fox snake, eastern massasauga, smallmouth salamander, spotted turtle, Blanchard's cricket frog, wood turtle, eastern box turtle, Northern Goshawk, Red-shouldered Hawk, Bald Eagle, Merlin, Cerulean Warbler, Hooded Warbler, prothonotary warbler, yellow-throated warbler, gray wolf, moose, Indiana bat, eastern pipistrelle, and woodland vole. Refer to MNFI Community Abstracts and DNR Wildlife Action Plan for more complete lists of special concern species.

L. NORTHERN WHITE CEDAR

1) Cover Type Characteristics:

Northern white cedar is a dominant or associate tree species in several natural communities. In the rich conifer swamps that it dominates, common associates are black and white spruce, balsam fir, white pine, hemlock, paper birch, red maple, and tamarack, and alder and hazelnut shrubs. White cedar can also dominate upland sites, most notably those with thin soil overlying dolomitic bedrock, such as along the Niagra escarpment. Cedar swamps are climax communities that can maintain themselves for

hundreds of years, in the absence of any large scale disturbances, excessive herbivory, or alteration of hydrology. Due to past logging, most cedar swamps are even-aged and relatively young (about half the cedar stands on State Forest lands are <100 years old) with poor representation of seedling and sapling size/age classes (Heitzman et. al. 1997). This may be due to a number of factors including stand development stage, deer herbivory and/or lack of suitable regeneration substrates.

2) Retention Considerations:

Under-Represented Species. Cedar swamps contain a broad but variable mix of species. As such, decisions about retention aimed at increasing under-represented species should be made on a site-by-site basis. Where black ash occurs, current Emerald Ash Borer Guidance should be consulted to inform decisions on retaining ash.

Mast Producers. Mast producing tree species are uncommon in cedar swamps. However, opportunities may exist to maintain or increase representation of soft mass shrub species.

Structure. Given the high shade tolerance of cedar, its long potential lifespan (informally reported at 600+ years, Lee Frelich, personal communication), the diverse structures and shade tolerances of its associated species, the vertical structure of cedar swamps can be complex. Vertical structure can be enhanced by retaining or promoting a broad array of species and size/age.

Cavity Trees, Standing Dead, and Downed Wood. Old cedar trees often have cavities; and due to its longevity and decay resistance, cavities may have long life spans. Given the current age structure of cedar stands, large snags and coarse woody debris may be at low density. To accelerate the development of DWD, girdling and felling of some trees is an option. Downed cedar may persist for long periods of time due to its decay resistance. When sufficiently decayed, cedar can be an important seedling establishment substrate (Marx 2005).

3) Wildlife and Plants:

Several plants and animals of concern occur in cedar dominated vegetative communities, with a greater number of rare plants occurring in cedar swamps than in any other habitat (Epstein et. al. 2002). Examples of rare plants include the calypso orchid (State threatened), limestone oak fern (State threatened), ram's head orchid (State special concern), black crowberry (State threatened). Examples of rare animals include the red-shouldered hawk (State threatened), eastern massasauga (State special concern), and Hine's emerald dragonfly (State endangered). Refer to MNFI Community Abstracts and the DNR Wildlife Action Plan for more complete lists of species of concern.

Cedar swamps provide habitat for many wildlife species, including critical winter habitat for deer, snowshoe hare, bobcat, black bear and gray wolf. Northern white cedar is a preferred species in deeryards because it provides excellent protection from snow and wind, and is the only browse species that, by itself, will maintain deer over winter in good health. Dense, mature stands exhibit narrow thermal ranges, warm average temperatures, low wind flow, and diminished hazardous conditions. High quality deer wintering areas are characterized by having approximately 50% of the landscape in productive, mature or over-mature, well-stocked (~100 square feet of basal area with a

minimum 70% canopy closure) coniferous stands. Shelter requirements for deer may vary considerably dependent on the magnitude of winter weather severity and the quality and quantity of food available. In order to perpetuate this valuable wildlife habitat, it may be necessary to identify areas that can be actively managed and regenerated without conversion to another type.

4) Rare Features/Communities:

Several rare communities contain cedar as a dominant or component species. For communities identified by the Wisconsin Natural Heritage Inventory, these include: Alvar, bedrock shore, clay seepage bluffs, and upland mesic cedar forests (Epstein et. al. 2002). The association of these communities with those identified by Michigan Natural Feature Inventory (Michigan State University Extension, 2006) is not established.

7. HOW TO CALCULATE THE AMOUNT OF RETENTION ACHIEVED

General goals for the amount, kind and distribution of retention will usually be set during the planning process for forest management activities or for long-term management plans. When setting up timber sales or marking timber, retention specifications can be refined, and the amount of retention calculated to verify whether the stand goals have been met.

Retention goals may be expressed as area based targets, or as basal area based targets depending on the type of silvicultural system to be employed. The amount of retention achieved can be calculated in several ways for each type of target. A few examples are described below, but are not the only ways to calculate the amount of area represented by retention.

A. Calculating Area-Based Retention:

Retention goals can be met using scattered individual trees, patches and/or clumps of trees. For stands greater than 10 acres, patches are recommended (Flatebo et. al., 1999), but scattered trees can also contribute to retention goals.

Area occupied by the selection of trees or patches designated for retention can be calculated using estimates for the ground area covered by the crowns of the retained trees. Three methods are described below as examples of how to calculate area-based retention:

METHOD 1: Area Retained Calculated From Stand Average Estimates of BA/Acre, Crown Diameter, and DBH for the Retained Trees

To estimate the amount of retention achieved:

- 1) Estimate the average basal area (BA/acre) of trees to be retained.
- 2) Estimate the average DBH and crown diameter of those trees.
- 3) Then look up the estimated the amount of retention (percent of stand area) represented by the selected trees measured by:
 - a. Select the appropriate average crown diameter section in Table 2.
 - b. Select the row corresponding to the average BA/acre of the retained trees.
 - c. Read across to the cell in the column for the average DBH of the retained trees.
 - d. Read the estimated percent of stand area represented by the projected crown area of the retained trees.

Table 2. Estimated % of Stand Area for the Average BA/Acre, DBH, & Crown Diameter of Trees Selected for Retention.

Average Crown diameter (ft)	Average BA/Acre for Retained Trees (ft ²)	Percentage of Stand Area						
		6" Ave. DBH	8" Ave. DBH	10" Ave. DBH	12" Ave. DBH	14" Ave. DBH	16" Ave. DBH	18" Ave. DBH
10	1	0.90%	0.50%	0.30%	0.20%	0.20%	0.10%	0.10%
10	2.5	2.30%	1.30%	0.80%	0.60%	0.40%	0.30%	0.30%
10	5	4.60%	2.60%	1.70%	1.10%	0.80%	0.60%	0.50%
10	10	9.20%	5.20%	3.30%	2.30%	1.70%	1.30%	1.00%
15	1	2.10%	1.20%	0.70%	0.50%	0.40%	0.30%	0.20%
15	2.5	5.20%	2.90%	1.90%	1.30%	0.90%	0.70%	0.60%
15	5	10.30%	5.80%	3.70%	2.60%	1.90%	1.50%	1.10%
15	10	20.70%	11.60%	7.40%	5.20%	3.80%	2.90%	2.30%
20	1	3.70%	2.10%	1.30%	0.90%	0.70%	0.50%	0.40%
20	2.5	9.20%	5.20%	3.30%	2.30%	1.70%	1.30%	1.00%
20	5	18.40%	10.30%	6.60%	4.60%	3.40%	2.60%	2.00%
20	10	36.70%	20.70%	13.20%	9.20%	6.70%	5.20%	4.10%
25	1		3.20%	2.10%	1.40%	1.10%	0.80%	0.60%
25	2.5		8.10%	5.20%	3.60%	2.60%	2.00%	1.60%
25	5		16.10%	10.30%	7.20%	5.30%	4.00%	3.20%
25	10		32.30%	20.70%	14.30%	10.50%	8.10%	6.40%
30	1			3.00%	2.10%	1.50%	1.20%	0.90%
30	2.5			7.40%	5.20%	3.80%	2.90%	2.30%
30	5			14.90%	10.30%	7.60%	5.80%	4.60%
30	10			29.80%	20.70%	15.20%	11.60%	9.20%

EXAMPLE 1: Retention in an aspen stand with white pine, oak and white spruce is estimated as follows:

- White pine, 1 ft² BA average over the stand, 25 ft. average crown diameter, 18" average DBH
- Oak, 5 ft² BA, 15 ft. average crown diameter, 10" average DBH
- White spruce, 1 ft² BA, 10 ft. average crown diameter, 6" average DBH

Using Table 2., look up the percent of area occupied by the retained white pine by looking down the left column to find the row corresponding to "25 foot average crown diameter" and "1 ft² BA/acre." Look across the row to the column headed "18-inch Ave. DBH" where the value '0.6%' can be read. The white pine selected for retention constitute about 0.6% of stand area.

To estimate the contribution of the retained oak, follow the steps to find the estimate of 3.7% of stand area. Likewise, the estimate for white spruce is 0.9% of stand area. The total amount retained in these trees 0.6% + 3.7% + 0.9% = 5.2%. Figure 1. below shows a hypothetical distribution of these trees.

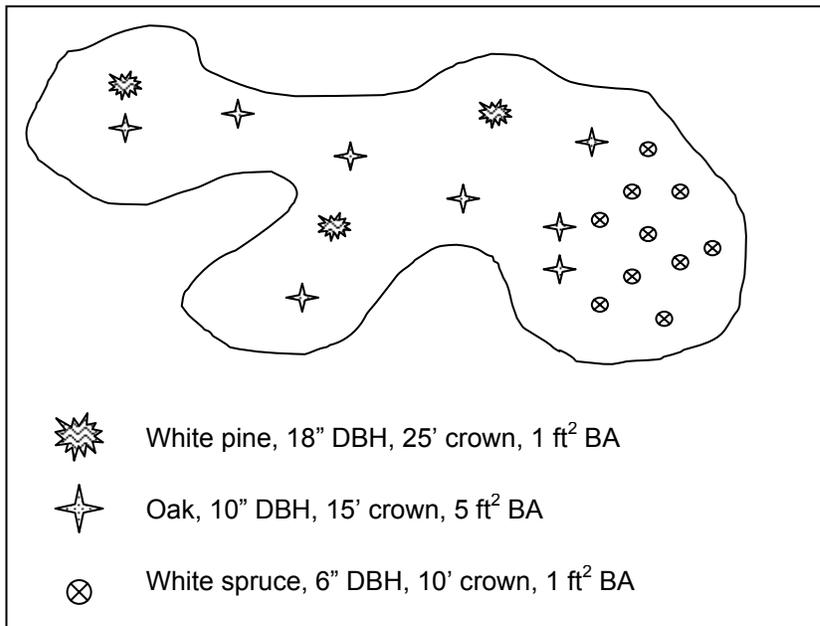


Figure 1. Distribution of Trees for Example 1, Method 1-Area Based Retention

METHOD 2: Area Retained Calculated From Average DBH of Individual Retained Trees

Use the DBH for retained trees with Table 3. below to estimate the amount of crown area for each tree, then multiply the estimate by the number of trees to be retained or the number per acre and stand acreage to obtain total acres retained.

Note that Table 3. is based on crown area measurements in northern hardwood stands (Godman and Tubbs, 1973). Since only northern hardwood species were measured in this study, further crown measurements are needed to refine these tables for use in other cover types. Until this information is available, use the following substitutions:

- For aspen or oak, use northern hardwood column.
- For spruce, fir, white pine, jack pine & red pine, use hemlock/conifer column.

Table 3 Average Tree Crown Area

DBH (in.)	Northern hardwood (sq. ft.)	Basswood (sq. ft.)	Hemlock/conifer (sq. ft.)
6	80	60	50
8	113	80	70
10	279	153	107
12	378	214	158
14	510	294	230
16	536	312	241
18	728	427	346
20	881	518	427
24	1207	712	612
26	1,306	773	662
30	1,571	933	806

Note: The crown areas above are average values and may vary for individual trees. Stand examiners have the discretion to modify these values based on individual tree characteristics.

METHOD 3: Area Retained Calculated From Patch Size

Where the spatial arrangement of features in the stand or the occurrence of special or sensitive areas suggests a logical patch boundary for retention, their contribution to the amount of area retained can be calculated using rough diameter in feet or chains and Table 4 below.

Likewise, where the intent is to lay out patches of varying sizes to achieve retention goals, the amount of area in each patch can be calculated using Table 4 to evaluate how many patches are necessary.

Table 4. Common Patch Sizes

Patch Size (ac.)	Patch Diameter	
	In Feet	In Chains (66 ft)
0.10	74	1.1
0.25	118	1.8
0.50	167	2.5
0.75	204	3.1
1.00	236	3.6

B. Calculating Basal Area-Based Retention

For uneven-aged stands and silvicultural systems, retention goals may be expressed in a percent of the residual basal area. Note that the retention goal is usually included in the residual basal area goal, not in addition to the normal silvicultural prescription for residual BA.

For example, the retention goal in a northern hardwood stand prescribed for selection harvest may be 5% of the residual basal area, with retained trees that meet the following characteristics:

- Under-represented species.
- Conifer/deciduous diversity.
- At least 3 mast trees/acre (>10" DBH where feasible).
- At least 1 large/super-canopy tree per 10 acres.
- At least 3 live cavity trees per acre, and up to 10 snags per acre as a combination of live cavity trees and snags (> 10" DBH where feasible).

The number of trees to leave for retention under this scenario can be calculated in two ways: as the number of trees per plot, or as the number of trees per acre.

METHOD 1: Basal Area-Based Retention Calculated As Number of Trees Per Plot

A common northern hardwood prescription is to mark the stand to a residual BA of 80 ft²/acre. Five percent of 80 = 4 ft²/acre (.05 x 80 = 4.). Using a 10-factor angle gauge, 4 ft²/acre will equate to 1 retention tree for every 2½ plots (10 ÷ 4 = 2½), or 2 trees every 5 plots. If the stand is cruised after marking and retention trees that are "in" are noted during the cruise, then the average BA/acre of retention trees is calculated the same way as the

average BA/acre is for the stand (i.e. total number of retention trees tallied divided by the total number of cruise points x 10).

METHOD 2: Basal Area-Based Retention Calculated as Number of Trees Per Acre

Another way of expressing basal area-based retention is in number of trees per acre. This can be calculated from an estimate of average DBH for the trees to be retained based on reconnaissance observations, and the silvicultural prescription for stand residual BA. Locate the residual BA in Table 5, then the row corresponding to the estimated average DBH for the retention trees. From the columns to the right, read the number trees per acre needed to meet a 3%, 5%, or 10% BA retention goal.

For example, the 5% column in Table 5. shows how many trees per acre of various diameter classes would be needed to satisfy the retention goal for a stand with residual basal area of 80 ft²/acre. In a stand with a 5% retention goal, this could be met with 5-12" trees, or 2-20" trees per acre. Usually retention goals will be accomplished using a combination of tree sizes.

Table 5. Number of Trees Per Acre Required to Meet Retention Goals of 3%, 5%, & 10%.

Target Residual BA	Retained Tree Average DBH	Number of Trees per Acre to Meet Retention Goal of:		
		3%	5%	10%
70	8	6	10	20
70	10	4	6	13
70	12	3	4	9
70	14	2	3	7
70	16	2	3	5
70	18	1	2	4
70	20	1	2	3
80	8	7	11	23
80	10	4	7	15
80	12	3	5	10
80	14	2	4	7
80	16	2	3	6
80	18	1	2	5
80	20	1	2	4
90	8	8	13	26
90	10	5	8	17
90	12	3	6	11
90	14	3	4	8
90	16	2	3	6
90	18	2	3	5
90	20	1	2	4

8. REFERENCES AND LITERATURE CITED

Abrams, M.D., 1998, The Red Maple Paradox, *Bioscience* 48: pp. 355-364.

Angers, V.A., Messier, C., Beaudet, M., Leduc, A., 2005, Comparing Composition and Structure in Old-growth and Harvested (selection and diameter-limit cuts) Northern Hardwood Stands in Quebec, *Forest Ecology and Management* 217: pp. 275-293.

Attiwill, P. M., 1994, The Disturbance of Forest Ecosystems - the Ecological Basis for Conservative Management, *Forest Ecology and Management* 63, no. 2-3: pp. 247-300.

Bebber, D.P., Cole, W.G., Thomas, S.C., Balsillie, D., Duinker, P., 2005, Effects of Retention Harvests on Structure of Old-growth *Pinus Strobus* L. Stands in Ontario, *Forest Ecology and Management* 205: pp. 91-103.

Benke, A.C., and J.B. Wallace, 2003, Influence of Wood on Invertebrate Communities in Streams and Rivers, pp. 149-178, in S.V. Gregory, K.L. Boyer, and A.M. Gurnell, editors. The Ecology and Management of Wood in World Rivers, *American Fisheries Society, Symposium 37, Bethesda, Maryland*.

Boyer, K.L., D. R. Berg, and S.V. Gregory, 2003, Riparian Management for Wood in Rivers, pp. 407-420, in S.V. Gregory, K.L. Boyer, and A.M. Gurnell, editors. The Ecology and Management of Wood in World Rivers, *American Fisheries Society, Symposium 37, Bethesda, Maryland*.

Burger, Timothy L. and John Kotar, 2003, *A Guide to Forest Communities and Habitat Types of Michigan*, Published by the Department of Forest Ecology and Management, University of Wisconsin-Madison.

DeGraff, R. M. 1987, Managing Northern Hardwoods for Breeding Birds, pp. 348-362, In: *Managing Northern Hardwoods. R. D. Nyland (ed.), Publication No. 87-03, Society of American Foresters. Washington D.C.*

Dickson, J. G., R. N. Connor, and J. H. Williamson, 1983, Snag Retention Increases Bird Use of Clear-cut, *Journal of Wildlife Management* 47: pp. 799-804.

Doepker, R.V., Thomasma, L.E. and Thomasma, S.A., 2001, *MIWildHab - Michigan Wildlife Habitats [computer program]*, Michigan Department of Natural Resources, Wildlife Division, Lansing, MI and Two by Two Wildlife Consulting, Grand Rapids, Michigan.

Dolloff, C.A., and M.L. Warren, Jr., 2003, Fish Relationships with Large Wood in Small Streams, pp. 179-194 in S.V. Gregory, K.L. Boyer, and A.M. Gurnell, editors, The Ecology and Management of Wood in World Rivers, *American Fisheries Society, Symposium 37, Bethesda, Maryland*.

Drapeau, P.A., LeDuc, A., Savard, J., Bergeron, Y., Vickery, W., Landscape Scale Disturbances and Changes in Bird Communities of Boreal Mixed-Wood Forests, *Ecological Monographs* 70: pp. 423-444.

Eagle, A.C., E.M. Hay-Chmielewski, K.T. Cleveland, A.L. Derosier, M.E. Herbert, and R.A. Rustem, eds., 2005, *Michigan's Wildlife Action Plan*, Michigan Department of Natural Resources, Lansing, Michigan, pp. 1592 <http://www.michigan.gov/dnrwildlifeactionplan>.

- Epstein, E., Judziewicz, E., Spencer, E., 2002, *Wisconsin Natural Heritage Inventory Natural Community Descriptions*, <http://dnr.wi.gov/org/land/er/communities/descriptions.htm#S>.
- Flatebo, G., Foss, C.R., Pelletier, S. K., 1999, *Biodiversity in the Forests of Maine*, University of Maine Cooperative Extension.
- Fowells, H.A., 1965, *Silvics of Forest Trees of the United States*, United States Department of Agriculture, *Agricultural Handbook No. 271*.
- Frelich, L.E., Lorimer, C.G., 1991, Natural Disturbance Regimes in Hemlock-Hardwood Forests of the Upper Great Lakes Region, *Ecological Monographs* 61: pp. 145-164.
- Frelich, L. E., 2002, *Forest Dynamics and Disturbance Regimes, Studies from Temperate Evergreen-Deciduous Forests*, Cambridge University Press, Cambridge, U.K.
- Godman, R. M. and Tubbs, C. H., 1973, *Establishing Even-Age Northern Hardwood Regeneration by the Shelterwood Method – A Preliminary Guide*, USDA Forest Service, NCFES, Research Paper NC-99.
- Goodburn, J.M., Lorimer, C.G., 1998, Cavity Trees and Coarse Woody Debris in Old Growth and Managed Northern Hardwood Forests in Wisconsin and Michigan, *Canadian Journal of Forest Research*, 28: pp. 427-438.
- Gregory, S.V., K.L. Boyer, and A.M. Gurnell, editors, 2003, *The Ecology and Management of Wood in World Rivers*, *American Fisheries Society, Symposium 37, Bethesda, Maryland*.
- Haartman, L., von, 1957, Adaptations in Hole-Nesting Birds, *Evolution* 11: pp. 339-347.
- Hautala H., Jalonen, J, Laaka-Lindberg, S., Vanha-Majamaa, I., 2004, Impacts of Retention Felling on Coarse Woody Debris (CWD) in Mature Boreal Spruce Forests of Finland, *Biodiversity and Conservation* 13: pp. 1541-1554.
- Heitzman, E., Pregitzer, K.S., Miller, R.O., 1997, Origin and Development of Northern White-Cedar Stands in Northern Michigan, *Canadian Journal of Forest Research* 27: pp. 1953-196.
- Herman K., Joseph, M., Oliver, T., Wagner, D., Scullon, H. W., Ferris, J., Kuhr, D., 2004, *A Process for Implementing Mesic Conifer Restoration on State Land, Western Upper Peninsula, Michigan*, Wildlife Division, Michigan Department of Natural Resources.
- Hunter, M. Jr., 1990, *Wildlife Forests and Forestry, Principles of Managing Forests for Biological Diversity*, Prentice Hall, Englewood Cliffs, New Jersey, pp. 62.
- Kearney, A., 2006, *Impacts of Beech Bark Disease on Stand Composition and Wildlife Resources in Michigan*, M.S. Thesis, Department of Entomology, Michigan State University, 118 pp.
- Kearns, L. J., Silverman, E.D., Hall, K.R. (in review), Black-throated Blue Warbler and Veery Abundance in Relation to Understory Composition in Northern Michigan Forests, *Wilson Journal of Ornithology* 118 pp.

Kneeshaw, D.D., Kobe, R.K., Coates, K.D., Messier, C., 2006, Sapling Size Influences Shade Tolerance Ranking Among Southern Boreal Tree Species, *Journal of Ecology* 94: pp. 471-480.

Krannitz, P. G., Duralia, T.E., 2004, Cone and Seed Production in *Pinus Ponderosa*: A Review, *Western North American Naturalist* 64: pp. 208-218.

Martin, A.C., Zim, H.S., Nelson, A.L., 1951, *American Wildlife and Plants*, Dover Publishing, Inc., New York.

Marx, L.M., 2005, *Substrate Limitations to Tsuga Canadensis and Betula Alleghanisensis Seedling Establishment*, M.S. Thesis, Department of Forestry, Michigan State University, 131 pp.

Mattson, K.G., Swank, W.T., Waide, J.B., 1987, Decomposition of Woody Debris in a Regenerating, Clear-cut Forest in the Southern Appalachians, *Canadian Journal of Forest Research*, 17: pp. 712-721.

McElhinny C., Gibbons, P., Brack, C., Bauhus, J., 2005, Forest and Woodland Stand Structural Complexity: Its Definition and Measurement, *Forest Ecology and Management* 218: pp. 1-24.

Menard, G., McNeil, R., Bouchard, A., 1982, Les Facteurs Indicatifs De La Diversite Des Peuplements D'oiseaux Forestiers Du Sud Du Quebec, *Naturaliste Canadien* 109: pp. 39-50.

Michigan Department of Natural Resources, 1994, *Water Quality Management Practices on Forest Land*.

Michigan State University Extension, 2006, *Michigan's Natural Communities, Draft List and Descriptions*, http://web4.msue.msu.edu/mnfi/data/MNFI_Natural_Communities.pdf.

Minnesota Forest Resource Council, 1998, *Wildlife and Mast*.

Naiman, R.J. and J.J. Latterell, 2005, Principles for Linking Fish Habitat to Fisheries Management and Conservation, *Journal of Fish Biology*, 67 (Supplement B), pp. 166-185.

Newbery, J.E., 2001, *Small Scale Disturbances and Stand Dynamics in Inonotus Tomentosus Infected and Uninfected Old-Growth*, M. Sc. Thesis, University of Northern British Columbia, Prince George, BC.

Newbery, J.T., Lewis, K.J., Walters, M.B., 2004, Estimating Time Since Death of *Picea Glauca* x *P. Engelmannii* and *Abies lasiocarpa* in Wet Cool Sub-boreal Spruce Forest in East-Central British Columbia, *Canadian Journal of Forest Research*, 34: pp. 931-938.

Newbery, J.T., Lewis, K.J., Walters, M.B., (in review), Composition, Structure and Dynamics of Partial-Cut and Unmanaged Wet Sub-Boreal Spruce Forests With and Without Root Disease Caused by *Inonotus Tomentosus*, *Canadian Journal of Forest Research*.

Michigan Natural Features Inventory (MNFI) web address:
<http://web4.msue.msu.edu/mnfi/pub/abstracts.cfm>.

Oliver, C. D., Larson, B. C., 1996, *Forest Stand Dynamics. Update Edition*, John Wiley and Sons, New York, New York, 520 pp.

- OMNR, 1998, *Silvicultural Guide for the Tolerant Hardwood Forests in Ontario*, Ontario Ministry Natural Resources, Queens Printer for Ontario, Toronto, 500 pp.
- OMNR, 2001, *Forest Management Guide for Natural Disturbance Pattern Emulation*, Technical Series, Version 3.1. Ontario Ministry Natural Resources, Queens Printer for Ontario, Toronto, 29 pp.
- OMNR, 2004, Ontario Tree Marking Guide. Version 1.1, Ontario Ministry Natural Resources, Queens Printer for Ontario, Toronto, 252 pp.
- Probst, J.R., Weinrich, J., 1993, Relating Kirtland's Warbler Population to Changing Landscape Composition and Structure, *Landscape Ecology* 8 (4): pp. 257-271.
- Randall, J.A., Walters, M.B., 2004, *Deer and Sedge Impact Tree Regeneration in Working Forests: Possible Restoration Treatments*, Michigan State University Extension, 3 pp.
- Rogers, L. L., Lindquist, E.L., 1992, Super-canopy White Pine and Wildlife, *The White Pine Symposium: History, Ecology, Policy and Management*, Duluth, MN, pp. 39-43.
- Schnurr, J.L., Ostfeld R.S., Canham, C.D., 2002, Direct and Indirect Effects of Masting on Rodent Populations and Tree Seed Survival, *Oikos* 96 (3): pp. 402-410
- Scott, R.E., Mitchell, S.J., 2005, Empirical Modeling of Windthrow Risk in Partially Harvested Stands Using Tree, Neighborhood, and Stand Attributes, *Forestry Ecology and Management* 218: pp. 193-209.
- Seelbach, P.W., M.J. Wiley, J.C. Kotanchik, and M.E. Baker, 1997, A Landscape-Based Ecological Classification System for River Valley Segments in Lower Michigan, Michigan Department of Natural Resources, *Fisheries Research Report* 2036, Ann Arbor.
- Singer M.T., Lorimer C.G., Crown Release as a Potential Old-Growth Restoration Approach in Northern Hardwoods, *Canadian Journal of Forest Research* 27: pp. 1222-1232.
- Simard M.J., Bergeron, Y., Sirois, L., 2003, Substrate and Litterfall Effects on Conifer Seedling Survivorship in Southern Boreal Stands of Canada, *Canadian Journal of Forest Research* 33: pp. 672-681.
- Stone, J., Parminter, J., Arsenault, A., Manning, T., Densmore, N., Davis, G., MacKinnon, A., 2002, Dead Tree Management in British Columbia, USDA Forest Service, *General Technical Report*, PSW-GTR-181. 2002.
- Tanabe, S.-I., Toda, M. J., Vinokurova, A. V., 2001, Tree Shape, Forest Structure, and Diversity of Drosophilid, Community, Comparison Between Boreal and Temperate Birch Forest, *Ecological Research*, 16: pp. 369-385.
- Thomas, J.W., R.J. Miller, H. Black, J.E. Rodiek and C. Maser, 1976, Guidance for Maintaining and Enhancing Wildlife Habitat in Forest Management in the Blue Mountains of Oregon and Washington, *Trans. North American Wildlife and Natural Resources Conference* 41: pp. 452-476.

Thomas, J. W., R.G. Anderson, C. Maser and E. L. Bull, 1979, Snags, In Thomas, J.W., ed. *Wildlife Habitats in Managed Forests: the Blue Mountains of Oregon and Washington*, USDA, Forest Service, *Agricultural Handbook* 553. pp. 60-77.

Tyrrell, L.E., Crow, T.R., 1994, Dynamics of Dead Wood in Old-Growth Hemlock Hardwood Forests of Northern Wisconsin and Northern Michigan, *Canadian Journal of Forest Research*, 24: pp. 1672-1683.

Tyrrell, L.E., Crow, T.R., 1994, Structural Characteristics of Old-Growth Hemlock-Hardwood Forests in Relation to Age, *Ecology* 75: pp. 370-386.

U.S. Fish & Wildlife Services, 1983, *Northern States Bald Eagle Recovery Plan*, USFWS, St. Paul, MN, 76 pp.

Whitney, G.G., 1986, Relation of Michigan Presettlement Pine Forests to Substrate and Disturbance History, *Journal of Ecology* 67: pp. 1548-1559.

Whitney, G.G., 1987, An Ecological History of the Great-Lakes Forest of Michigan, *Journal of Ecology* 75: pp. 667-684.

Zhang QF, Pregitzer KS, Reed DD, 2000, Historical Changes in the Forests of the Luce District of the Upper Peninsula of Michigan, *American Midland Naturalist* 143: pp. 94-110.