CHAPTER 24

TREE MARKING AND RETENTION GUIDELINES: THE SILVICULTURAL PRACTICE OF SELECTING TREES TO RETAIN AND REMOVE

The purpose of this chapter is to:

- Provide silvicultural guidelines for selecting trees to retain and remove to accomplish specific stand management objectives.
- Provide recommendations for stand-level tree and snag retention to accomplish sustainable forest management goals.
- Recommend content of written marking guidelines for prescription implementation.
- Clarify concepts and considerations related to why and how trees are selected and marked, including appropriate silvicultural methods.
- Clarify silvicultural terminology.

Selecting and marking trees to retain and remove is a fundamental silvicultural practice frequently applied to the management of even-aged and uneven-aged forest stands. The selection of trees to retain and remove is most commonly applied as part of the following treatments:

- Intermediate treatments:
  - Cleaning (release)
  - Thinning
  - Improvement
  - Sanitation
- Even-aged regeneration methods:
  - Seed tree
  - Shelterwood
- Uneven-aged selection systems.

In addition, the selection and retention of reserve trees and snags may also be included in the following treatments:

- Liberation (release)
- Salvage
- Clearcut, coppice, and overstory removal regeneration methods.

The selection of trees to retain and to remove is a key element of most silvicultural methods.

Silvicultural practices are prescribed to satisfy sustainable landowner goals and achieve stand management objectives. When forest stands are chosen for cutting, the desired characteristics of the remaining and/or regenerating trees and stand are of primary importance. The desired residual and future stand composition and structure guide the selection of trees for retention and trees for removal. During intermediate treatments, the focus is on which trees will be retained and managed until the next entry and beyond. When applying even-aged regeneration methods, the focus is on controlling stand composition and structure to facilitate the recruitment and development of desirable regeneration. However, some trees can be selected for retention beyond the regeneration period to achieve objectives other than regeneration. Uneven-aged stand management systems integrate regeneration, thinning, and harvesting practices; tree retention focuses on which trees will be retained and managed until the next entry and beyond, including timber crop trees, wildlife trees and snags, and other non-timber objectives. The selection of trees to retain guides marking operations and strongly influences the selection of trees to cut.

Specific tree characteristics can be defined to achieve specific management objectives; for example, sawtimber crop tree or wildlife tree characteristics can be specified. Often, multiple objectives are identified for individual stands, and a variety of tree characteristics may be desired. Sometimes, individual trees can satisfy multiple objectives; for example, a large oak tree can provide wildlife mast and habitat, recreational aesthetics, soil and water protection, and eventually quality sawtimber when harvested. Some trees are retained for only a brief period (e.g. one cutting cycle), some are retained for longer periods (e.g. end of or beyond current stand rotation) and then cut, and some are retained until senescence and death (during or beyond current rotation). The number of trees to retain and the desired residual stand density depend on management objectives, silvicultural methods, forest type and species, stand and tree condition, and site.

Silvicultural prescriptions often detail tree selection and marking guidelines to accomplish stand management objectives and achieve landowner property goals. Marking guidelines for prescription implementation often include:

- Stand management objectives, including specific objectives of the marking treatment (purpose of the cut)
- Silvicultural method(s), such as:
  - Regeneration method
  - Intermediate treatment
- Residual stand composition – desired species mix
- Residual stand structure, for example:
  - Target residual basal area (sometimes by size class)
  - Target residual crown cover
  - Target number and size of canopy gaps per acre
- Characteristics of trees to retain (e.g. timber crop trees, wildlife trees, reserve trees):
  - Objectives and specific characteristics
  - Number per acre and distribution
- Snag management, including size, number, and distribution
- Trees-to-cut characteristics – order of removal
- Special considerations.

Marking guidelines should be recorded and discussed with the marking crew before field marking operations are initiated. Written stand management objectives, prescriptions, marking guidelines, and evaluations of results provide valuable information which should be documented and filed for future reference.

Timber Management Considerations

The cover type chapters in this handbook provide silvicultural guidelines to optimize tree and stand vigor, and timber quantity and quality. Most silvicultural practices implemented over the life of a stand focus on crop tree management, density management (e.g. residual basal area), and the selection of trees to cut (order of tree removal). Selecting and marking trees to retain and remove is an important part of most silvicultural practices implemented to achieve timber management goals.

Timber crop trees are trees selected to become a component of a future commercial harvest. These trees are selected for retention and their crowns released from competition to optimize tree vigor and focus growth on the most desirable trees. Sawtimber crop trees are the best quality, high vigor trees of desirable species that are targeted for (near) final harvest; they will be grown to rotation age or maximum desired size class.

General Sawtimber Crop Tree Selection Criteria (see specifications on the following pages)

- Low risk of mortality or failure (main stem breakage)
- Good crown vigor
- Good timber quality
- Desirable species

Crop tree management is an important part of most marking operations. The number of crop trees to retain and the desired residual stand density depend on management objectives, silvicultural methods, forest type and species, stand and tree condition, and site. In addition to timber crop trees, identify and retain other trees to provide multiple benefits. The selection of trees for retention strongly influences which trees will be cut.

Selecting Trees to Cut

Before selecting trees to cut, identify desired residual stand composition and structure, and tree retention criteria (including both timber and non-timber goals and objectives). If all trees except seed trees or reserve trees will be cut, then specify seed or reserve tree objectives and characteristics, and the removal of all other trees to a minimum diameter (usually 1 inch dbh). For partial cuts, the characteristics of trees to cut are also delineated.

If timber management is a primary goal, and stand management objectives include the promotion of stand and tree vigor, and the production of high quality sawtimber products, then the selection of trees to cut should apply the following order of removal to achieve the desired residual stand composition and structure.

Order of Removal (see definitions below)

1. High risk of mortality or failure (unless retained as a wildlife tree)
2. Release crop trees
3. Low crown vigor
4. Poor stem form and quality
5. Less desirable species
6. Improve spacing

The order of removal may vary somewhat depending on landowner goals, stand management objectives, and silvicultural treatment; for example, a shelterwood seed cut or the presence of exotic invasive species may elevate the removal of undesirable species. The order of removal should be clearly stated in writing prior to any marking and cutting operations.

Following are definitions and specifications for terms used in crop tree selection and order of removal guidelines. Some forest cover type chapters detail additional species specific criteria and guidelines.

Risk is the probability that a tree will die or fail (main stem will break) within a specified time period. It is an estimate of probable mortality or failure within the next cutting cycle.

- High risk: tree has any of the following:
  - Tree infected with canker rot fungus (see species specific criteria in cover type chapters)
  - Canker affects >50% of the stem's circumference
  - Butternut canker affects >20% of combined circumference of the stem and root collar
  - White pine blister rust canker located where stem failure would cause a loss of >50% of the crown
  - Horizontal crack on a canker's face
  - Open crack on main stem is in contact with another defect, such as decay, a canker, or a weak union (V-shaped)
  - Crack goes completely through the stem or is open (bark and wood fibers split) for >5' of length
  - Two open cracks occur on the same stem segment
  - Cavity and associated decay affects >40% of the stem's cross-sectional area
  - Decay in main stem results in <1" of sound wood for every 6" in diameter (2" for every 6" if a cavity is present)
  - Leaning tree with horizontal crack, long vertical crack, or buckling wood on the underside of the tree
  - Leaning tree with recent root lifting
  - More than 33% of roots severed, decayed, or otherwise compromised
  - Signs of cambium miners, such as two-lined chestnut borer or bronze birch borer
  - >50% of the crown is dead
  - >75% of the leaves subnormal in size or abnormal in color (this does not include color changes caused by nutrient deficiencies, fungal leaf spots, or other causes where crown recovery is expected)
- Moderate risk: tree has any of the following:
  - Canker affects 10-49% of the stem's circumference
  - Cavity and associated decay affects 10-39% of the stem's cross-section
  - 10-33% of roots severed, decayed, or otherwise compromised
  - 10-49% of the crown is dead
- Low risk: tree has no signs of defect or could have all of the following:
  - Canker affects <10% of the stem's circumference
  - Cavity and associated decay affects <10% of the stem's cross-section
  - <10% of roots severed, decayed, or otherwise compromised
  - <10% of the crown is dead

Vigor refers to active healthy well-balanced growth of individual trees. It describes the tree's potential to grow at a rapid rate and increase volume. Vigor is evaluated based on tree crown class, size, and condition.

- Low vigor: Trees with a poor silhouette, poor leaf condition, and many branch stubs on upper and middle bole (see high risk). In hardwoods, a concentric crown less than half full; in conifers, a poor crown/length ratio.
- Moderate vigor: Trees with a fair silhouette and fair leaf condition. In hardwoods, a 1/2-3/4 full concentric crown; in conifers, a fair crown/length ratio.
- Good vigor: Dominant or codominant trees with a good silhouette and healthy leaves. In hardwoods, a full concentric crown; in conifers, a good crown/length ratio.

Quality (timber) refers to stem form, soundness, and potential timber value of individual trees. Timber quality is evaluated based on log length, diameter, and defect.

- Poor timber quality: Useable length far short of the average for the site; dbh/length ratio poor; permanently sub-merchantable in length; or heavy crook or sweep will not cut out.
- Moderate timber quality: Useable length fairly commensurate with site; dbh/length ratio fair; usable length stopper on upper bole; or moderate crook or sweep will not cut out.
- Good timber quality: Useable length commensurate with site; dbh/length ratio good; no usable length stoppers; and slight crook or sweep will cut out. Good hardwood sawtimber quality includes the potential for at least one 16' butt log of tree grade 2 or better.

Effects of defects on timber quality vary significantly, depending on the type and severity of a defect, tree species, and site factors. Due to this complexity, information specific to defect types and tree species is not described in this chapter. Some forest type chapters detail species specific indicators of timber quality; for example, the Northern Hardwood Chapter includes information about the effects of defects on timber quality.

Species selection is based on sustainable landowner property goals, stand management objectives, site quality, silvics, and stand condition. Desirable sawtimber crop trees are well-adapted to the site and of commercial value.

Spacing refers to the distance between stems and crowns of desirable trees, and the equal distribution of growing space.

Application of the Order of Removal:
The order of removal is most commonly applied during intermediate treatments, particularly thinning, and uneven-aged selection treatments.

- First, determine desired residual stand composition and structure, including crop tree characteristics and tree retention criteria (objectives, characteristics, number, and distribution), and target residual stocking.
- Then, select and mark trees to cut following the order of removal and until the desired residual stocking is achieved.

For example, during a free thinning applied to a small sawtimber stand managed only for timber production, first mark for cutting all high risk trees and check residual stocking. If stocking exceeds target residual, next identify sawtimber crop trees and mark the least desirable adjacent trees to provide 1-3 sided crown release. Check residual stocking. If stocking exceeds target residual, next mark for cutting low vigor then poor quality trees. Often, target residual stocking will be achieved during this step. If not, then continue to mark, focusing on undesirable species, tree spacing, and the lowest vigor and poorest quality trees that remain, until target residual density is attained. Marking stops when actual residual stocking is near the target objective stocking.

In addition to timber crop trees, other trees are typically retained to achieve non-timber management objectives (e.g. cavity trees for wildlife). Criteria for selection and retention should be specified before marking. Selecting these trees for retention may require periodic departure from strict application of the order of removal (e.g. retain some high risk trees as cavity trees and future snags for wildlife habitat). In some cases, it may be necessary to mark these trees to ensure that they will not be cut.

In many timber marking operations, crop trees are identified, and the order of removal is applied to select and mark trees to cut. In cases where most trees will be cut and relatively few trees will be retained (e.g. shelterwood or reserve tree retention), then it may be more efficient to mark only trees to retain.

Evaluation of Silvicultural Prescription Implementation of Selectively Marked Stands (Marking Evaluation)

The Division of Forestry is responsible for reviewing and approving cutting notices and reports on lands under the Managed Forest Law, State Lands, County Forest Lands, and other programs to determine if the timber sale establishment field work is consistent with the management prescription described on the cutting notice or silvicultural prescription for the harvest. The review and approval process may include an evaluation of marked uneven-aged harvests and even-aged intermediate thinnings to ensure that the prescribed target basal area and order of removal have been adequately achieved. An evaluation sheet and procedure, found as an appendix to this chapter, may be used to determine if a silvicultural prescription was successfully implemented during the harvest marking/designation process. It is only applicable to selectively marked stands where residual basal area and order of removal play an important role in the success of the treatment with a focus on timber production. The use of this evaluation tool/process is not mandatory and other methods may be used to determine if a marking meets a minimum standard of acceptability.

Measuring whether or not a marked harvest has successfully implemented the silvicultural prescription is measurable, but involves professional judgment as well. The evaluation process (see appendix A) attempts to quantify the success of marking and provide a procedure that promotes consistency and defines expectations. It is up to professional judgment of the evaluator to determine whether or not to utilize this evaluation process. When evaluating selectively marked harvests, plots will be taken to determine if the timber sale preparer has correctly implemented the written silvicultural prescription for the harvest.

Three tests of acceptability must be satisfied when using this marking evaluation procedure:

1. The trees designated for harvest on a plot must follow the standard order of removal for that timber type as described in the appropriate DNR Silviculture Handbook chapter or other criteria specified in the recommended prescription for the stand. If the order of removal is not followed, then the plot will be considered unacceptable (e.g. target basal area is achieved by marking a crop tree for harvest while leaving an adjacent low vigor tree).
2. Plots generally must have a residual basal area that falls within 10 ft^2 below and 20 ft^2 above (or +/-15 ft^2 for target basal area ending in 5) the agreed upon target residual basal area described in the prescription to be considered acceptable (e.g. if the agreed upon target is 90 ft^2/acre, then a plot would "pass" if it contained 80 – 110 ft^2 residual basal area).
3. 70% of the area (defined by plots) measured must meet the combined minimum criteria (i.e. residual BA and order of removal) for the marking to be considered acceptable.

The Marked Timber Evaluation Procedure and Evaluation Sheet located in Appendix A of this chapter have been developed by department staff to assist with evaluating a marked harvest. In the event that an initial evaluation suggests that a timber marking is unacceptable, additional plot work may be necessary to ensure an accurate, defensible evaluation. This procedure does not intend that a statistically sound sample be taken. It is provided as one of a number of decision making tools in the evaluation process of a marked timber harvest. Other considerations needing evaluation may include: BMPs for water quality, invasive species, National Heritage Inventory (NHI) data, archeological, historical, cultural, green tree retention, and stump marks.

Wildlife Management Considerations

Prior to cutting a stand, identify specific trees that have high value for wildlife. Retain sufficient numbers of these wildlife trees to meet landowner goals and to provide for sustainable management of forest-dependent wildlife. Both stand and landscape level considerations may play a role in the decision process. Wildlife trees provide important structure (standing or as down woody debris) and function when managing an ecosystem. Wildlife trees can be periodically re-evaluated. Removal of wildlife trees can occur, but some should be allowed to senesce and die.

In southern Wisconsin, black cherry is a good example of a wildlife tree; large, vigorous specimens are uncommon and their fruit is eaten by many birds and mammals. In the north, large, tall white pines or hemlock groves are often reserved. Any current or future cavity or mast-producing tree is a good candidate to retain. If a few very large trees remain from previous harvests, continuing to reserve these trees can contribute to cavity, snag and species diversity objectives.

A variety of mast-producing trees suited to the habitat type should receive management consideration. Vigorous trees of a variety of species will best provide the benefits of mast production. Mast trees may provide other wildlife benefits. As an example, the "wolf tree" is often chosen as a wildlife tree. Though reserving wolf trees may mean sacrificing some timber production, they are among the best mast and cavity producers.

Wisconsin's wildlife Species of Greatest Conservation Need (SGCN) were identified by WDNR (2005). SGCNs that utilize snags and/or cavity trees include northern flying squirrel, Osprey, Red-headed Woodpecker, Black-backed Woodpecker, northern long-eared bat, silver-haired bat, and hoary bat. Bat species prefer large, spreading, snags with the bark still on. SGCNs associated with large trees are Bald Eagle, Northern Goshawk, Red-Shouldered Hawk, Acadian Flycatcher, Cerulean Warbler, and Prothonotary Warbler. Coarse woody debris associates among the SGCN include Louisiana Waterthrush, four-toed salamander, and American marten. In addition to these, many of the more common forest wildlife species benefit from the presence of large trees, cavity trees, snags, and coarse woody debris.

To minimize the impact of timber harvest on cavity-dwelling wildlife, it is important that a reasonable number of appropriate snag and cavity trees be left after harvest. For most forest ecosystems the current understanding of the biology of cavity-using wildlife is too limited to employ species by species estimates of snag requirements. A guideline of three or more cavity trees and as many snag trees as possible per acre should meet the requirements of most cavity-dwelling wildlife. A range of sizes and decay stage of snags will best achieve the objective of providing this habitat requirement. Large snags (18"DBH or larger) are particularly valuable. Large snags can accommodate a variety of wildlife. Larger wildlife species require larger trees, while smaller species can still use the large snags. Additionally, large cavity trees tend to remain available for a longer time. Some long-lived wildlife species will use this resource seasonally over a period of years and some species will use the same resource across generations. Cavity-dwelling wildlife range in size from bats and chickadees to pileated woodpeckers and black bears.

The long-term nature of snag and large diameter cavity tree availability must also be considered. To maintain an appropriate number of snags, the recruitment rate for snags must balance the rate of loss through decay. One solution is to leave some trees with poor form and low economic value to serve as future snag trees. Cavity requirements might sometimes be more easily attained with living trees since the number of residual snags is so unpredictable. Because one can assume that a portion of those trees set aside to become the second generation of snag trees will fall down before they die, it is advisable to leave more than will ultimately be needed as snags.

Some individual trees are favored by wildlife for a variety of reasons. They may be better producers of a food resource or they may be well suited to be used as a territorial marker. As an example, the Yellow-bellied Sapsucker is a common primary cavity excavator. Individuals tend to return regularly to the same trees for foraging. If preferred trees are removed, then excavations will be transferred to another tree. Maintaining trees with signs of sapsucker activity will concentrate this activity to relatively few trees and reduce impacts on timber yields. Retain trees with signs of sapsucker activity or other regular wildlife use.

In addition to selecting trees with poor form as future snag trees, it is sensible to choose trees that are infected with heart rot. These trees will be of low value and may already have cavities. Diseased trees can be identified by the presence of conks of heart rot fungi, wounds such as broken branch stubs and fire scars, dead portions of the crown, and woodpecker holes. These trees may provide habitat niches to species requiring loose bark which may not be available on older snags.

Within forests, inclusions may be found where seasonal ponding of water occurs. These ponds are called “vernal pools” (Rogers and Premo 1997). Vernal pools are characterized as small, seasonal, ephemeral, pools or ponds that lack predatory fish (Colburn 2004). Due to the lack of predators, these pools are important areas for amphibians and invertebrates to reproduce. The actual size used as definitional criteria of these “small” pools is debatable. Rogers and Premo (1997) described size range of vernal pools as “from a puddle to an acre or more.” Vernal pools contain species of aquatic flora and fauna not found throughout the terrestrial matrix. The frequency and distribution of vernal pools are of importance to their function in maintaining or enhancing biodiversity. Prior to timber harvesting, vernal pools should be identified and assessed, and for those pools deemed important to achieving biodiversity conservation goals (e.g. pools infrequent on the landscape and pools with known concentrations of uncommon species), protection measures should be specified. Some vernal pools should be buffered to protect amphibian foraging and breeding habitat. Retention of down woody debris nearby will improve habitat for some amphibians. Harvesting should avoid felling trees into or skidding through vernal pools, and avoid rutting in the nearby vicinity. Vernal pools may not be apparent at certain times of the year due to their ephemeral lack of standing water or during periods of snow cover. Signs of vernal pools include water marks on tree trunks, changes in ground layer vegetation, and discoloration of litter on the forest floor.

Many of the forest cover type chapters in this handbook provide wildlife management considerations, and specific species are sometimes addressed. Guidance for more specific snag and den tree management prescriptions can be found in *"A Landowner's Guide to Woodland and Wildlife Management"* (University of Wisconsin-Extension, Publication Number 193578). This publication was developed to help the private landowner better manage woodlands for wildlife. It is a good source of information for specific snag requirements of some of our most common cavity-using birds and provides other information useful when managing mature forests for wildlife.

<u>Wildlife Tree and Snag Retention Criteria</u>

- Large trees for habitat structure (e.g. nest trees)
  - Some low risk, good vigor trees to sustain long life
  - Some moderate to high risk, moderate to low vigor (decadent) trees to provide near-term future snags and coarse woody debris
  - Desirable species; strive for species diversity
- Mast trees for food
  - Low risk
  - Good crown vigor
  - Strive for species diversity; hard-mast producers generally preferred over soft-mast producers
- Cavity (den) trees for shelter
  - With cavities in bole
  - Larger diameter cavity trees are particularly desirable
  - Strive for species diversity
- Snags for habitat, shelter, and food
  - Larger diameter snags are particularly desirable
  - Strive for diversity in species and level of decay

<u>Large trees</u> are at least 12 inches dbh, and preferably greater than 18 inches dbh. Large trees >18 inches dbh are uncommon. However, they provide structural diversity that increases the availability of habitat niches and can benefit an array of wildlife. Important structural features include: tall canopies that contribute to vertical stratification, large crowns and branches, and loose, furrowed bark. Importantly, the development of large trees is required for the recruitment of large cavity trees, snags, and down coarse woody debris.

<u>Mast trees</u> are living trees that produce fruit and nuts that are consumed as food by wildlife. Large crowned vigorous trees generally produce the most mast. Increasing numbers of mast trees facilitate increased populations of some species. Retain as many mast trees as possible.

<u>Cavity (den) trees</u> are living trees that are partially hollow and used by wildlife for shelter. Large diameter cavity trees, especially those >18 inches dbh, can provide the greatest array of benefits. Increasing the number and size of cavity trees facilitate increased populations of some species. Retain as many large diameter cavity trees as possible.

Snags are standing dead trees. Snags benefit many species of wildlife; large diameter snags can provide the greatest array of benefits. Eventually, snags become downed coarse woody debris that also benefits wildlife and other ecosystem processes. Increasing the number and size of snags facilitates increased populations of some species. Other than the physical space occupied, snags do not compete with living trees. Retain all snags present that do not provide a threat to human safety; those that are determined to be a threat can be cut and retained on site as coarse woody debris.

For general wildlife management objectives, retain as many large trees, mast trees, cavity trees, and snags as possible in concordance with stand management objectives and landowner property goals. Wildlife trees retained can be scattered uniformly or irregularly distributed, as single trees, groups, and patches. Large trees and mast trees may benefit from crown release. Cavity trees do not necessarily require release, but in some cases crown release can prolong tree life and cavity benefits. Clearly designate, in writing and/or by marking, which trees should be retained (not cut) prior to any cutting operations.

Figure 24-1. Large, old yellow birch tree

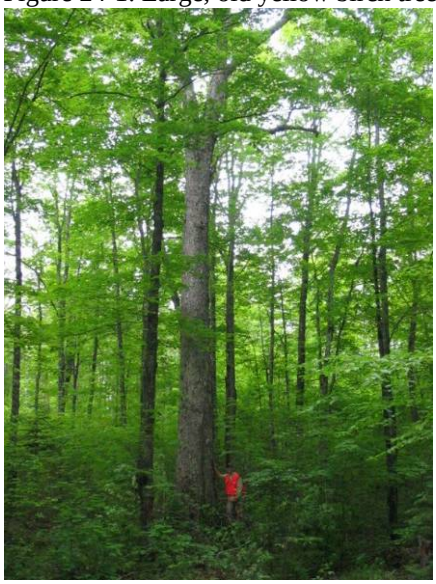

Photo by Colleen Matula

Figure 24-2. Cavity tree

Joseph O'Brien, USDA Forest Service, Bugwood.org

Figure 24-3. Snag

Photo by Jeff Martin, J-Mar Photography

Figure 24-4. Mast

Paul Wray, Iowa State Univ., Bugwood.org

Aesthetic Management Considerations

Forest Aesthetics management guidelines should be referenced when designing aesthetic considerations for forest management application. Aesthetics involves not only individual marking decisions but long term planning and design. General aesthetic tree retention criteria have been developed, but specific characteristics and retention design will be highly variable depending on landowner preferences and stand specific considerations.

Aesthetic Tree Retention Criteria

- Low risk
- Good crown vigor
- Desirable species depend on landowner goals and site conditions, and may consider:
  - Lifespan
  - Foliage color
  - Flowers and fruits
  - Bark characteristics
  - Crown architecture, such as large spreading crowns and unusually shaped trees

Water Quality Management Considerations

Wisconsin Best Management Practices (BMP) for Water Quality guide forest management practices to maintain water quality. Forest management in stands where the maintenance of water quality is a primary objective and concern, involves not only individual marking decisions but long term planning and design. General water quality tree retention criteria have been developed, but specific characteristics and retention design will be highly variable depending on landowner goals and specific stand and site conditions and considerations.

Water Quality Tree Retention Criteria

- Low risk
- Good crown vigor
- Desirable species depend on landowner goals and site conditions, and may consider
  - Lifespan
  - Tolerance of saturated soils and flooding

Biodiversity and Endangered Resources Management Considerations

Many biodiversity and endangered resources issues are addressed at the landscape level, and then through the protection of special habitats. Within managed stands, identify and protect element occurrences and special habitats. Follow general wildlife management guidelines; select and retain wildlife trees, including reserve trees as dispersed and aggregated individuals, groups, and patches. By integrating the identification of special habitats and microsites with the retention of reserve tree patches, multiple benefits can be achieved. Areas to consider when selecting patches for retention include groups of trees that are older or have high species diversity, sites where understory composition exhibits high diversity or uncommon species, vernal pools, seeps, wet depressions, cliffs, rock outcrops, ravines, and caves. Some of the forest cover type chapters in this handbook provide biodiversity management considerations, and specific species are sometimes addressed.

Biological legacies are organisms, reproductive portions of organisms, and biologically derived structures and patterns inherited from a previous ecosystem. Compositional legacies influence ecosystem function, and can include trees, understory plants, fungi, invertebrates, and other animals. For example, mycorrhizal fungi and microbial decomposers are potential compositional legacies whose nutrient cycling functions are essential in maintaining site productivity. Structural legacies, such as trees, snags, and surface organic matter (including down woody debris) also influence ecosystem function, and provide habitat for organisms.

In forests managed for timber production, variable retention harvesting retains biological legacies from the harvested stand for integration into the new stand to achieve ecological objectives. Structural legacies selected for retention often include large trees, large snags, and large down logs to provide refugia and to structurally enrich the new stand. Large structures take a long time to develop and are not easily replaced. Important characteristics of trees selected as biological legacies are: species diversity; size class representation, especially very large trees; tree health, including both healthy and decadent trees; and heterogeneous distribution as dispersed individuals and aggregated patches. Reserve trees intended for future harvest provide biological legacies as living (usually large) trees. Reserve trees can be allowed to persist, developing into large trees, snags, and eventually large coarse woody debris. Management of biological legacies requires adaptive silvicultural methods to promote stand level heterogeneity, compositional and structural complexity, and ecosystem diversity.

Figure 24-5. Biological legacies following windstorm.

Figure 24-6. Biological legacies following fire.

Photos by Joe Kovach

Reserve Trees

Reserve trees are living trees, ≥5 inches dbh, retained after the regeneration period under even-aged or two-aged silvicultural systems. They are retained well beyond stand rotation, and for purposes other than regeneration. They may be harvested eventually or retained to complete their natural lifespan (becoming a snag and then coarse woody debris). Reserve trees can be dispersed uniformly or irregularly, as single trees or aggregated groups or patches, or any mixture thereof. Synonyms include standards and green tree retention.

A legacy tree is a specific type of reserve tree that is usually older (past typical rotation age) and sometimes a remnant of a previous stand. Legacy trees may not be present in some stands, depending on management and disturbance history. These trees are individual old trees that function as refuges or provide other important structural habitat values. Legacy trees are meant to provide long term ecological benefits and are generally kept in perpetuity.

The characteristics of desirable reserve trees are highly variable and depend on the intended benefits, the species present, stand condition, and site. Desired compositional and structural attributes may be present when trees are selected and stands are rotated, or additional time may be required for development.

Typical characteristics of desirable individual reserve trees (either scattered or within patches) include:

- Large size (tree height, diameter, crown dimensions) for the species and site.
  - If large trees are lacking, then potential future large trees can be selected.
- Older trees with large size and rough bark.
- A mix of vigorous and decadent trees.
  - Vigorous trees of long-lived species can enable long-term retention and potentially yield a variety of benefits.
  - Decadent trees can provide current and future cavity trees, as well as future snags and down coarse woody debris.
- A mix of species, including locally uncommon species and mast trees.

The development and maintenance of large structures (vigorous trees, cavity trees, snags, down woody debris) and species diversity is typically encouraged.

Generally, poor candidates for individual reserve trees include:

- Relatively small (height, diameter, crown), suppressed to intermediate trees.
- Relatively young trees within the stand.

These smaller, younger trees are retained in reserve groups and patches along with larger, older trees.

Exceptions to these typically desirable and generally poor reserve tree characteristics will occur.

Note: Application of the tree retention guidelines for County Forests is slightly different than stated within the handbook. Refer to a County's 15 Year plan for details on tree retention for a particular County Forest. That version should be used to evaluate and approve sales for that respective County forest. Foresters should be aware that other third party certified lands may have their own tree retention guidelines.

Benefits of Reserve Tree Retention

Silvicultural practices are designed to manipulate vegetation to achieve management objectives. At its foundation, silviculture is based on understanding and working with ecological processes. Silvicultural practices that more closely emulate natural disturbance and stand development processes are more likely to sustain a wide array of forest benefits. Most natural disturbance regimes and events retain compositional and structural legacies in heterogeneous patterns and create ecological complexity. Silvicultural practices that develop and maintain reserve trees in managed stands can enable the promotion of ecological complexity – composition, structure, and pattern.

The retention of reserve trees can provide a "lifeboat" function that contributes to the conservation of biological diversity (see preceding section). These structures facilitate the perpetuation of some biota (plant and animal species and genotypes) on site. They also perpetuate habitat for re-colonization and occupation. They can improve landscape connectivity, facilitating the movement of some organisms. Reserve trees influence reorganization and recovery processes in post disturbance ecosystems; they can sustain functional roles and modify the post-disturbance environment.

The actual benefits achieved through the retention of reserve trees can be variable, depending on such factors as landscape composition and structure, stand composition and structure, site, retention design, and management objectives.
Some specific potential benefits include:

- Timber Production
  - Reserve high quality trees for future harvest
  - Perpetuation of tree species diversity
- Wildlife and Plant Habitat (Biodiversity)
  - Cover
  - Cavity (den) and nest trees
  - Display locations
  - Food (foraging, hunting)
  - Future snags and down woody debris (coarse and fine)
  - Habitat diversity
  - Protect special habitat
  - Travel corridors
- Aesthetics
  - Limit line of vision
  - Break up “clearcut” look
  - Retain visually unique trees
  - Provide diversity in future stand
- Water and Soil Quality
  - Reduce run-off
  - Reduce erosion
  - Maintain water and nutrient cycles
- Miscellaneous
  - Buffer adjacent stands
  - Protect cultural resources
  - Landmarks, such as marker trees and witness trees

Potential Costs of Reserve Tree Retention

The retention of reserve trees in actively managed stands can provide ecological benefits desired by landowners and society. However, there are also costs or trade-offs. The primary potential cost is reduced timber yield at the stand-level. Also, retention can result in less available habitat for some wildlife species, particularly those that prefer open, treeless habitat. However, impacts on long-term forest ecosystem sustainability and productivity are uncertain; current understanding suggests that the maintenance of ecological complexity will more likely sustain long-term productivity.

Some specific potential costs include:

- Potential additional operational costs to manage reserve tree retention
- Potential for reduced timber growth rates maintained by larger, older trees
- Potential for reduced short-term stand-level timber yields by foregoing harvest of some trees
- Potential for epicormic branching
- Potential for stem and crown damage during stand harvest
- Potential for crown dieback and mortality following harvest
- Potential for windthrow, particularly on wet or shallow soils, or for shallow rooted species
- Potential damage to younger stand if reserve trees are harvested during mid-rotation
- Reduced growth rates of regeneration occurring beneath reserve trees
- Potential sites for pathogen breeding and maintenance
- Potential for reduced habitat for or increased predation of certain wildlife species

Considerations for Reserve Tree Retention

Reserve overstory trees will shade portions of a newly developing stand. Increased numbers of dispersed reserve trees and trees with larger and denser crowns will cause more shading. Furthermore, reserve tree crowns can expand over time, increasing shading effects. Shading by reserve trees potentially can reduce growth within portions of newly developing established even-aged stands. The point at which growth reductions become significant depends on a variety of factors, including: stand management objectives (for reserve trees and young trees), growth rates and potential development of reserve trees, growth rates and shade tolerance of species comprising the new stand, site quality, understory competition, and potential damaging agents. In general, to promote optimum growth of established even-aged stands of reproduction, (nearly) full sunlight is preferred. Under even-aged management systems, when objectives include the retention of reserve trees beyond the regeneration establishment phase, crown cover of <20% generally (for most species and conditions) will not significantly reduce vigor, growth, and development of most of the developing stand. If reserve trees are dispersed and expected to survive and grow, crown cover will increase over time; 15% crown cover is a generally recommended maximum for dispersed retention at final rotation. If reserve trees are aggregated, then shading impacts will be reduced; total crown cover retained could be greater, and will depend on stand management objectives.

Excessive shading may also be a concern when regenerating shade intolerant species in small stands or in narrowly linear stands, surrounded by relatively mature forest. In such cases, it may be necessary to retain fewer reserve trees. Alternatively, there may be opportunities to redesign stand boundaries creating a larger stand with increased opportunities for internal tree retention.

Reserve tree retention is a generally recommended silvicultural practice for stands ≥10 acres. It is encouraged in smaller stands, but operational, shading, and other biological issues may limit application.

Insect and disease issues and potential impacts on tree health should be another consideration in reserve tree selection and design. Regeneration methods are designed to foster the vigor of the regenerating stand. Although the imminent mortality of some reserve trees may be desirable or acceptable, typically some vigorous trees will be retained with the expectation of continued growth and survival (perhaps for a long time). When regenerating a stand and retaining reserve trees, potential risks to tree health should be evaluated, and methods implemented to reduce risks while achieving stand management objectives. In most cases, well designed regeneration and retention strategies can minimize risks; however, stand and site conditions may limit options in some cases. Refer to the cover type chapters in this handbook and forest pest management guidelines to appropriately consider and address insect and disease risks when selecting and designing regeneration methods and reserve tree retention for a specific stand and site.

Two examples of how insect and disease considerations can influence reserve tree selection and design:

- Red pine: Retaining red pine reserve trees when regenerating a new red pine stand may significantly increase the risk of Sirococcus and Diplodia incidence within the young stand. This risk is highly variable geographically; where experience has shown the risk to be significant, then retaining red pine reserve trees over red pine regeneration would be poor silviculture. In such cases, retain other species (e.g. oak) as reserve trees if available; if not available, then it may not be possible to retain reserve trees as generally recommended, but consider including representation of other species as part of stand regeneration to provide increased options for future managers. Red pine can be an excellent reserve tree when regenerating other species (e.g. aspen or oak).
- Jack Pine: In general, retaining jack pine reserve trees when regenerating a new jack pine stand is not recommended, because of the risk of budworm outbreaks. When regenerating jack pine, other species (e.g. oak) should be retained as reserve trees if available. Jack pine can be retained as a reserve tree when regenerating other species.

Representation of reserve trees can range from none to many. If silviculture is to simulate, to some extent, natural disturbance processes, then most actively managed stands should include some level of structural retention. To accomplish general sustainable forestry goals that include multiple stand management objectives, recommended representation could typically range from 5-15% of stand area or crown cover. In some stands, particularly intensively managed single objective stands (e.g. maximize short-term economic returns, maximize pulp production, or maximize populations of wildlife species that prefer completely open, treeless habitat), landowners may choose to not retain reserve trees. In some stands, with appropriate species and site characteristics, where the optimization of tree vigor and timber quantity and quality is a minor concern, adaptive silvicultural practices that retain 20-60% cover could be considered by the landowner. It is recommended that sound reasons and expected impacts be documented when the decision is to retain reserve trees at less than or greater than the recommended level of 5-15% of stand area or crown cover.

Distribution of reserve trees can be evenly or irregularly dispersed individuals, groups, and patches.

Retention in aggregated patches generally provides the most benefits, including:
- patches of habitat that maintain forest floor, understory plants, and vertical structure within the patch, and increase compositional and structural diversity,
- more heterogeneity across the stand,
- less damage to retained trees during harvesting operations, and
- less impact on regeneration in stand matrix.

Patch retention should consider retention of large trees, cavity trees, and snags within the patches. Reserve patches can be thinned during the even-aged rotational harvest of the matrix; however, retention of unthinned patches potentially provides the greatest benefit. Patches can be located to complement other management objectives or respond to stand conditions; for example, patches can be located in riparian management zones, to provide connectivity between stands, and to protect sensitive sites (e.g. cliff faces and vernal pools) or endangered resources. Patches should be >0.1 acres and generally <2.0 acres, but can be larger; patches, particularly large ones, should be documented as retention patches.

Retention of evenly dispersed individual trees also provides unique benefits, including:
- retention of comparatively more large trees, and
- wide distribution of structural benefits (large trees, snags, and coarse woody debris) and seed sources.

Retention of irregularly dispersed individual trees and small groups provides another strategy; this can be particularly useful to develop feathered edges to stands and reduce abrupt transitions and edge effects.

The general recommended strategy is to retain irregularly distributed patches along with scattered groups and individuals.

Table 24.1 Patch sizes for retention and approximate dimensions (circular and square)

Area (acres)	Diameter (feet)	Square (feet)
0.1	74	66 x 66
0.25	118	104 x 104
0.5	167	148 x 148
0.75	204	181 x 181
1.0	236	209 x 209
1.5	288	256 x 256
2.0	333	295 x 295

Stand representation and spatial distribution patterns of reserve trees can be highly variable. The goal of heterogeneity of conditions indicates a wide array of retention strategies. Retention design, including amount to retain, species, and distribution, can enable the production of increased benefits and minimize potential costs. Criteria to consider when determining desired representation and distribution include: landowner goals and stand management objectives, current and desired stand and community condition, characteristics of current and desired plant and animal species, potential damaging agents, site, and landscape characteristics. Detailed landscape analysis and planning that clearly addresses the sustainable allocation of resources, including the production of timber and the conservation of biodiversity, can improve upon stand-based management guidelines (such as those offered herein).

Figure 24-7. Reserve trees retained in patches.

Photo by Jeff Martin, J-Mar Photography

Figures 24-8. Reserve trees retained as a group.

Photo by Joe Kovach

Figures 24-9. Reserve trees retained irregularly as individuals.

Photo by Joe Kovach

Recommendations for Retention in Managed Stands: Reserve Trees, Mast Trees, Cavity Trees, and Snags

Sustainable forest management is implemented within a framework defined by landowner goals and objectives, ecosystem condition and potential, and sustainable silvicultural systems and practices. Forests are cultivated to provide a variety of socio-economic and ecological benefits. Sustainable forest management integrates multiple management goals and objectives into most silvicultural systems and the management of most stands and landscapes.

Most stands that are actively managed include timber production as a management goal (often in concert with other goals). Tree retention typically focuses on crop tree selection and regeneration methods. To satisfy multiple objectives and provide multiple benefits, retain additional trees to achieve non-timber management objectives. Integrate the following recommendations for tree and snag retention into the management of most forest stands:

- Even-aged rotations
  - Retain ≥3 (if available), preferably large, snags per acre.
  - Retain reserve trees and/or patches at 5-15% crown cover or stand area, including large vigorous trees, mast trees, and cavity trees. Reserve tree retention is a generally recommended silvicultural practice for stands ≥10 acres. It is encouraged in smaller stands, but operational, shading, and other biological issues may limit application.
- Even-aged intermediate treatments
  - Retain ≥3 (if available), preferably large, snags per acre.
  - Retain ≥3 (if available), preferably large, cavity trees per acre.
  - Retain ≥3 (if available), preferably large, mast trees per acre.
  - If previously established, manage reserve trees and patches. Management may include timber harvesting or passive retention. Consider retaining ≥3 trees per acre to develop into large, old trees and to complete their natural lifespan. These trees may also satisfy cavity and mast tree recommendations. These trees will often become large snags and coarse woody debris.
- Uneven-aged systems
  - Retain ≥3 (if available), preferably large, snags per acre.
  - Retain ≥3 (if available), preferably large, cavity trees per acre.
  - Retain ≥3 (if available), preferably large, mast trees per acre.
  - Consider retaining ≥3 trees per acre to develop into large, old trees and to complete their natural lifespan. These trees may also satisfy cavity and mast tree recommendations. These trees will often become large snags and coarse woody debris.

In cases where these recommendations for retention are not applied, then sound reasons and expected impacts of deviation should be documented.

When applying retention recommendations, be sure to consider:

- Individual trees can provide multiple benefits and fulfill the intent of more than one of the above recommendations. For example, three large oak trees with cavities could satisfy the mast tree and cavity tree recommendations, as well as the large, old tree consideration.
- Retention of both vigorous and decadent trees will provide an array of benefits.
- In general, species diversity is encouraged when selecting trees to retain.
- Large trees and snags are >12 inches dbh, and preferably >18 inches dbh.
- Trees retained can be scattered uniformly throughout a stand or irregularly dispersed, as single trees, groups, and patches. The general recommended strategy is to retain irregularly distributed patches along with scattered groups and individuals.
- Retention in aggregated patches generally provides the most benefits for wildlife and biodiversity. Also, patches retained can satisfy multiple benefits; for example, at stand rotation, an internal or adjacent unharvested buffer along a stream (RMZ) could provide a portion of reserve tree retention as well as satisfy BMP (water quality) recommendations. Patches should be >0.1 acres and generally <2.0 acres, but can be larger; reserve tree patches, particularly large ones, should be documented as retention patches.
- Estimating the amount of retention can be measured using the following techniques: crown area of retention trees, GPS area around a retention patch, densitometer of crown closure, and basal area of residual trees.
- Harvesting of reserve trees may occur in the future or may be foregone to achieve other benefits. Retain reserve trees for at least one-half the minimum rotation age of the new stand (e.g. retain reserve trees at least 20-25 years if regenerating aspen). Consider retaining some trees to develop into large, old trees and to complete their natural lifespan; these trees will often become large cavity trees, snags, and coarse woody debris.
- Retaining down coarse woody debris already present. Minimize disturbance, including crushing, fragmenting, and displacing existing down coarse woody debris except on roads, skid trails, and landings.

- Retain as many snags as possible. Retention of snag diversity (species and size) can potentially provide the greatest array of benefits. Snags that are determined to be a threat to human safety can be cut and retained on site as coarse woody debris.
- Clearly designate, in writing and/or by marking, which trees should be retained prior to any cutting operations.

References

Amaranthus, M.P. 1998. The importance and conservation of ectomycorrhizal fungal diversity in forest ecosystems: lessons from Europe and the Pacific Northwest. USDA For. Serv., Pac. NW Res. Stn., Gen. Tech. Rep. PNW-GTR-431

Astrom, M., M. Dynesius, K. Hylander, and C. Nilsson. 2005. Effects of slash harvest on bryophytes and vascular plants in southern boreal forest clear-cuts. J. Appl. Ecol. 42:1194-1202

Bunnell, F.L., I. Houde, B. Johnston, and E. Wind. 2002. How dead trees sustain live organisms in western forests. USDA For. Serv. Gen. Tech. Rep. PSW-GTR-181

Colburn, E.A. 2004. Vernal pools: Natural history and conservation. McDonald & Woodward, Blacksburg, VA.

Christensen, N.L., A.M. Bartuska, J.H. Brown, S. Carpenter, C. D'Antonio, R. Francis, J.F. Franklin, J.A. MacMahon, R.F. Noss, D.J. Parsons, C.H. Peterson, M.G. Turner, and R.G. Woodmansee. 1996. The report of the Ecological Society of America committee on the scientific basis for ecosystem management. Ecol. Appl. 6(3): 665-691

Crow, T.R., A. Haney, and D.M. Waller. 1994. Report on the scientific roundtable on biological diversity convened by the Chequamegon and Nicolet National Forests. USDA For. Serv., NCFES, Gen. Tech. Rep. NC-166

DeGraaf, R.M. and A.L. Shigo. 1985. Managing cavity trees for wildlife in the Northeast.
USDA For. Serv., NEFES, GTR NE-101

DeGraaf, R.M., M. Yamasaki, W.B. Leak, and J.W. Lanier. 1992. New England wildlife: management of forested habitats. USDA For. Serv., NE For. Exp. Stn., Gen. Tech. Rep. NE-144.

Demaynadier, P.G. and M.L. Hunter Jr. 1998. Effects of silvicultural edges on the distribution and abundance of amphibians in Maine. Conserv. Biol. 12(2): 340-352

Evans, A.M. and M.J. Kelty. 2010. Ecology of dead wood in the Northeast. Forest Guild. 21 pp.

Franklin, J.F., R.J. Mitchell, and B.J. Palik. 2007. Natural disturbance and stand development principles for ecological forestry. USDA For. Serv., N. Res. Stn., GTR NRS-19, 44pp.

Fridman, J. and M. Walheim. 2000. Amount, structure, and dynamics of dead wood on managed forestland in Sweden. For. Ecol. and Mgmt. 131: 23-36.

Goodburn, J.M. and C.G. Lorimer. 1998. Cavity trees and coarse woody debris in old-growth and managed northern hardwood forests in Wisconsin and Michigan. Can. J. For. Res. 28:427-438

Hammond, H.E.J., D.W. Langor, and J.R. Spence. 2004. Saproxylic beetles (Coleoptera) using Populus in boreal aspen stands of western Canada: spatiotemporal variation and conservation of assemblages. Can. J. For. Res. 34:1-19

Helms, J.A. (Editor). 1998. The Dictionary of Forestry. Society of American Foresters.

Hunter, M.L. and F.K.A. Schmiegelow. 2010. Wildlife, forests, and forestry: Principles of managing forests for biological diversity (2nd ed.). Prentice Hall.

Hura, C.E. and T.R. Crow. 2004. Woody debris as a component of ecological diversity in thinned and unthinned northern hardwood forests. Nat. Areas. J. 24:57-64

Hyvarinen, E., J. Kouki, and P. Martikainen. 2006. Fire and green-tree retention in conservation of red-listed and rare deadwood-dependent beetles in Finnish boreal Forests. Conserv. Biol. 20(6):1711-1719

Maser, C. and J.M. Trappe (eds.). 1984. The seen and unseen world of the fallen tree.
USDA For. Serv., PNW For. and Rge. Exp. Stn., GTR PNW-164

McComb, B.C. 2007. Wildlife habitat management: concepts and applications in forestry. CRC Press

McGee, G.G., D.J. Leopold, and R.D. Nyland. 1999. Structural characteristics of old-growth, maturing, and partially cut northern hardwood forests. Ecol. Appl. 9(4):1316-1329

Michigan Department of Natural Resources. 2006. Within-stand retention guidance. State of Michigan, Dept. Natl. Resour., IC4110.

Minnesota Forest Resources Council. 2005. Sustaining Minnesota forest resources: voluntary site-level forest management guidelines. Minnesota For. Resour. Council, St. Paul, Minnesota.

National Commission on Science for Sustainable Forestry. 2007. Conserving biodiversity through sustainable forestry. National Council for Science and the Environment, Wash. D.C. 174 pp.

Niemela, J. 1997. Invertebrates and boreal forest management. Conserv. Biol. 11(3):601-610

Nyland, R.D. 1996. Silviculture: Concepts and Applications. McGraw-Hill.

OMNR. 2002. Forest management guide for natural disturbance pattern emulation, version 3.1. Ont. Min. Nat. Resour. Queens Printer for Ontario. Toronto.

OMNR. 2004. Ontario tree marking guide, version 1.1. Ont. Min. Nat. Resour. Queens Printer for Ontario. Toronto.

Perkey, A.W., B.L. Wilkins, and H.C. Smith. 1993. Crop Tree Management in Eastern Hardwoods.
NA-TP-19-93. USDA For. Serv., NESPF, Morgantown, WV.

Rogers, E. and D. Premo. 1997. Managing for biodiversity. White Water Associates, Inc., Amasa, MI., 34pp.

Rosenvald, R. and A. Lohmus. 2008. For what, when, and where is green tree retention better than clear-cutting? A review of the biodiversity aspects. For. Ecol. And Mgmt. 255(1):1-15

Serrouya, R. and R. D'Eon. 2004. Variable retention forest harvesting: Research synthesis and implementation guidelines. Sustainable Forest Management Network, Alberta, Canada 51 pp.

Seymour, R.S. and M.L. Hunter Jr. 1999. Principles of ecological forestry. In: Hunter, M.L. Jr. (ed.) Composition in managing forests for biodiversity. Cambridge Univ. Press, NY. pp 22-61.

Smith, D.M. 1962. The Practice of Silviculture, 7th ed. New York: Wiley.

Taylor, D.A.R. 2006. Forest management and bats. Bat Conservation I International. 13 pp.

University of Wisconsin – Extension. A landowner's guide to woodland and wildlife management.
State of Wisconsin, Univ. Wisc. – Extension, Publ. No. 193578

Wisconsin Department of Natural Resources. 1995. Wildlife and your land.
State of Wisconsin, Dept. Natl. Resour., PUBL-WM-216-225

Wisconsin Department of Natural Resources (WDNR). 1995. Wisconsin's biodiversity as a management issue. State of Wisconsin, Department of Natural Resources, Pub-RS-915

Wisconsin Department of Natural Resources. 1995. Wisconsin's Forestry Best Management Practices for Water Quality. State of Wisconsin, Dept. Natl. Resour., PUB-FR-093

Wisconsin Department of Natural Resources. 2003. Wisconsin Forest Management Guidelines. State of Wisconsin, Dept. Natl. Resour., PUB-FR-226

Wisconsin Department of Natural Resources. 2006. Old-growth and old forests handbook. State of Wisconsin, Dept. Natl. Resour., Hndbk. 2480.5

Woodley, S.J., G. Johnson, B. Freedman, and D.A. Kirk. 2006. Effects of timber harvesting and plantation development on cavity-nesting birds in New Brunswick. The Canadian Field Naturalist 120:298-306

Woodall, C.W., S.N. Oswalt, and R.S. Morin. 2007. Attributes of down woody materials in hardwood forests of the Eastern United States. USDA For. Serv., SRS, e-GTR-SRS-101, pp. 144-153

Appendix A. Marked Timber Evaluation Procedure & Evaluation Sheet

This evaluation sheet can be used to evaluate marked uneven-aged harvests and even-aged intermediate thinnings. Stand management objectives, prescriptions, and residual target basal area should be clearly stated prior to marking. The attached field data collection sheet and procedure is designed as a tool to help evaluate how effectively the prescribed silviculture system has been applied. Once the timber harvest has been marked, it may be evaluated for meeting criteria set forth in the WI DNR Silviculture Handbook, forest management plan, and/or cutting prescription (i.e. MFL Cutting Notice or public land Timber Sale Notice and Cutting Report Form 2460-001).

NUMBER OF PLOTS

Recommendation for the minimum number of variable radius plots (10 BAF) to measure: 1 plot for every 4 acres of the sale area with a minimum of 5 well-spaced plots per stand within the sale area (e.g., 32 acre sale / 4 = 8 plots). Plots shall be systematically spaced to sample the entire sale area; except on large timber sales, professional judgment can be used to determine if marking evaluation is warranted over the entire sale area or only on a subsample of the sale area if initial results are good. If the initial sample does not pass for any reason, additional sampling may be necessary. Note: It is not the intent of the evaluation to take a statistically sound number of plots. Plot intensity will increase if problems are noted in the initial sample(s). The follow-up sample(s) may be up to one plot per acre.

PLOT SAMPLING

Basal Area and Individual Tree Quality: At each plot, data will be collected on the Marked Timber Evaluation Sheet. The data includes marked (**C**ut Tree) and residual (**L**eave Tree) basal area (BA) by species and size classes (5-11" pole, 11-14" sm. saw, 15-19" med. saw, and 20+" lg. saw). BA will be determined using a 10 BAF tool. At each plot, tally individual trees under species code (if needed) and also under basal area size class columns. It may be easiest to first tally marked trees (C - Cut) and then residual trees (L - Leave). Trees may be tallied with "dot tally" or utilizing the growing stock classifications listed below. Classifying the trees may help paint a picture of the quality of the marking job.

Each tree may be classified based on tree risk, vigor and quality as follows:

- "**1**" means crop tree: See definition in Silviculture Handbook ch. 24
- "**2**" means average tree: Better than class 3 but not a crop tree; acceptable growing stock.
- "**3**" means obvious cut tree: High risk (See definition in Silviculture Handbook ch. 24); obvious low vigor/quality tree to release higher classified tree; unacceptable growing stock.

PLOT EVALUATION

The marking of each individual plot will be evaluated (graded) on the following basis:

- Residual basal area
- Stand quality - order of removal is followed to achieve target residual basal area
- Other considerations: canopy gaps, paint marks, insect & disease concerns, BMPs, wildlife considerations, endangered resource considerations, etc.

If any of these criteria receive an unacceptable rating, then the plot receives an unacceptable rating. Each of these criteria are described in greater detail below.

Basal Area Rating: For an individual plot to be rated acceptable, the residual basal area must fall within the following range around the stated Target BA:

- For Target BA ending in zero: the acceptable range will be from Target BA minus 10 to plus 20 ft^2 (e.g., Target BA 90 ft^2 then acceptable for plot is ≥ 80 and ≤ 110 ft^2).
- For Target BA ending in five: the acceptable range will be from Target BA minus 15 to plus 15 ft^2 (e.g., Target BA 85 ft^2 then acceptable for plot is ≥ 70 and ≤ 100 ft^2).

However, no matter which method is utilized, the lower acceptable BA will be no less than the B-line for even-aged stocking guides and 70 ft^2 for NH uneven-aged stands.

The plot will be rated based on the residual BA as follows:

➢ **"+"** The residual basal area falls within the following range around the stated Target BA:

- Target BA ending in zero: residual BA within -10 to +20 ft^2
- Target BA ending in five: residual BA within -15 to +15 ft^2

➢ **"–"** The residual basal area falls outside the specified range around the stated Target BA

➢ **"NA"** Used for plots that have an acceptable reason for not falling within the target BA range, for example:
- Initial BA was below the target BA range
- Residual BA was below target BA range after only high risk trees were removed
- Plot is within an uneven-aged gap
- Aspen patch to be removed (stand inclusions)
- Residual BA is > the target BA range and silviculture guidelines were followed leaving the BA appropriately higher than target range. Examples might include the following:
  - No more than 1/3 of the initial BA should be removed
  - Hemlock or white cedar are present as stand inclusions (at least 50% of BA)
  - High percentage of basswood

Stand Quality - Order of Removal Rating: Designation of trees for harvest at each plot will be evaluated and rated in regards to improving and maintaining overall stand quality by correctly applying the order of removal as agreed upon in the cutting prescription, or, if not listed in cutting prescription, as defined in ch. 24 of the Silviculture Handbook.

Application of the standard order of removal (See Silviculture Handbook ch. 24):
1. High risk of mortality or failure (unless retained as a wildlife tree)
   Were high risk trees removed?
2. Release crop trees
   Did crop trees needing release have at least partial release by marking neighboring tree of lesser quality?
   Note: Some crop trees may already have full or partial release, therefore requiring no further release.
3. Low crown vigor
   Were trees of the low crown vigor marked for removal?
4. Poor stem form and quality
   Were trees with poor stem form and quality relative to adjacent individual trees marked for removal?
5. Less desirable species
   Is species diversity maintained and desired species composition achieved?

In order to better quantify what is and is not acceptable variation in order of removal marking, the growing stock classification system listed above (i.e., crop tree, average tree, obvious cut tree) may help in the evaluation process. The order of removal criteria can then be individually evaluated and rated. Finally, each plot is given a total order of removal rating as follows:

- **"+"** **Good**: tree designation correctly applied within the plot.
  Example: If the marking follows the order of removal, then the rating is "+" (Good).

➢ **"0"** **Acceptable**: Tree designation is not perfect <u>but</u> is acceptable (still meets stand objectives).
Example: If you are questioning a tree that is marked vs. lesser quality tree left, and they both are in the same classification (both are average), then, although not desirable, this would be an example of acceptable variation and the rating is "0" (Acceptable).

➢ **"–"** **Unacceptable**: Tree designation is not consistently and correctly applied within the plot (cutting marked tree(s) will result in degradation of stand quality and/or vigor).
Example: If the marked tree is in a higher classification than the lesser quality tree retained (average class tree marked and obvious cut tree left, or crop tree marked and average class tree left), then this would be unacceptable and the rating is "-" (Unacceptable).

➢ **"NA"** Used for plots that have an acceptable reason for not following criteria.
Example: No high risk trees, no crop trees on plot, or desired residual stocking achieved before a criterion applied.

***Other Plot Evaluation Considerations*:** Other considerations, as stated in the cutting prescription, that may need to be evaluated on plot include: canopy gaps, paint marks, insect & disease concerns, BMPs, wildlife, and endangered resources.

These considerations can be rated, such as the canopy gap example below, or described in plot remarks.

Canopy Gap Rating - For uneven-aged management, evaluate canopy gaps (appropriate size & cleaned of poor quality saplings & poles). Criteria are found in the Silviculture Handbook, chs. 21 and 40.

- **"+"** means appropriate size gap (see table 40.8), and it is designated to be cleaned.
- **"–"** means the gap was not appropriate size or not correctly designated to be cleaned.
- **"NA"** means a gap did not fall within the plot.

Paint Marks - Marked trees must have an adequate volume of paint and have adequate stump mark at ground level. Preferably stump marks will be located in crevasses of the stump. In order to facilitate marking, checking, and harvesting, there should be at least two marks on opposite sides of the tree.

***Plot Evaluation Remarks*:** Use space below stand quality rating for plot remarks, including other considerations.

***Plot Grade*:** Grade each plot as good, acceptable, or unacceptable based on basal area, order of removal, and other considerations. If any of these criteria receive an unacceptable rating, then the plot is graded unacceptable.

- **"G" or "+"** **Good**: Marking correctly achieved basal area target range, and quality factors correctly applied.
- **"A" or "0"** **Acceptable**: Marking achieved basal area target range, and quality factors acceptable.
- **"U" or "-"** **Unacceptable**: Marking did not achieve basal area target range and/or quality factors incorrectly applied.

SALE EVALUATION

The data collected may be used to assess compliance of stand wide timber marking with acceptable silviculture guidelines and/or stated cutting prescriptions. Summarize the data, and compute average cut and residual basal area, as well as plot grades. Whereas it is acceptable for wider individual plot BA variation, stand averages should be closer to the target BA (+/-10%).

Minimum requirements for sale approval are:

- Average residual BA within +/-10% of target BA
- At least 70% total plot grades tally "G" or "A"
  - If excessive number of plots are rated A (>40%), then a follow-up discussion should occur with the marker with possible corrections and/or opportunities for improvement.

If evaluation determines that the proposed treatment meets these minimum timber marking standards and conforms to stated silviculture guidelines as found in the WI DNR Silviculture Handbook and/or cutting prescription (i.e. MFL Cutting Notice or public land Timber Sale Notice and Cutting Report Form 2460-001), then the sale will be deemed to meet silvicultural standards.

If evaluation determines that the proposed treatment does not meet these minimum timber marking standards and/or does not conform to stated silviculture guidelines as found in the WI DNR Silviculture Handbook and/or cutting prescription (i.e. MFL Cutting Notice or public land Timber Sale Notice and Cutting Report Form 2460-001), then the sale does not meet silvicultural standards and corrective action should be implemented. Once corrected, the sale may be re-evaluated using the above process.

MARKED TIMBER EVALUATION SHEET Rev. 6/10	Property:	Sec.	T	R	Desc.
Estimator:	Date:	Covertype:			Page ___ of ____

Pt. #	Species Code						Basal Area (Target BA_____)						Stand Quality - Order of Removal					Total OOR Rating	Other Rating e.g.Gap	Total Plot Grade
							Pole 5-9/11	Saw-Sm 9/11-14	Saw-Md 15-19	Saw-Lg 20+	TOTAL	BA Rating	Risk Trees Removed	Crop Trees Released	Vigor	Quality	Species Selection			
1C																				
1L													Comments:							
2C																				
2L													Comments:							
3C																				
3L													Comments:							
4C																				
4L													Comments:							
5C																				
5L													Comments:							
6C																				
6L													Comments:							
7C																				
7L													Comments:							
8C																				
8L													Comments:							
9C																				
9L													Comments:							
10C																				
10L													Comments:							
C-Tots												C-Total	Comments regarding the stand:							
C-Avg												C-Avg								
L-Tots												L-Total	Stand Quality Rating: Each aspect of stand quality is rated separately.							
L-Avg												L-Avg	+ = Good: Plot met expectations for Order of Removal.							

TREE CLASSIFICATION: (Trees recorded by class for species and basal area size class.)
1 = Obvious crop tree: See definition in Silviculture Handbook Chapter 24
2 = Average tree: Better than class 3, but not a crop tree.
3 = Obvious cut tree: High risk, suppressed, low vigor to release higher classed tree.

0 = Acceptable: Plot did not fully achieve Order of Removal, but still meets management objective.
- = Unacceptable: Plot did not implement the Order of Removal correctly.
Other: Paint volume, Stump marks, Canopy gaps, I & D, Marks on two sides, etc.
TOTAL PLOT GRADE: G = Good; A = Acceptable; U = Unacceptable.

Appendix B. Summary Tables

Table 24.2 General sawtimber crop tree selection criteria (see Table 24.5)

- Low risk of mortality or failure
- Good crown vigor
- Good timber quality
- Desirable species

Table 24.3 Order of removal for timber management (see Table 24.5)

1. High risk of mortality or failure (unless retained as a wildlife tree)
2. Release crop trees
3. Low crown vigor
4. Poor stem form and quality
5. Less desirable species
6. Improve spacing

Table 24.4 Wildlife tree and snag selection criteria

- Large trees for habitat structure (e.g. nest trees)
  - Some low risk, good vigor trees to sustain long life
  - Some moderate to high risk, moderate to low vigor (decadent) trees to provide near-term future snags and coarse woody debris
  - Desirable species; strive for species diversity
- Mast trees for food
  - Low risk
  - Good crown vigor
  - Strive for species diversity; hard-mast producers generally preferred over soft-mast producers
- Cavity (den) trees for shelter
  - With cavities in bole
  - Larger diameter cavity trees are particularly desirable
  - Strive for species diversity
- Snags for habitat, shelter, and food
  - Larger diameter snags are particularly desirable
  - Strive for diversity in species and level of decay

Table 24.5 Evaluation of growing stock – tree risk, vigor, and timber quality

	Good Growing Stock	**Fair Growing Stock**	**Poor Growing Stock**
	Low Risk	**Moderate Risk**	**High Risk**
Risk	Tree has no signs of defect, or could have all of the following: • Canker affects <10% of the stem's circumference • Cavity and associated decay affects <10% of the stem's cross-section • <10% of roots severed, decayed, or otherwise compromised • <10% of the crown is dead	Tree has any of the following: • Canker affects 10-49% of the stem's circumference • Cavity and associated decay affects 10-39% of the stem's cross-section • 10-33% of roots severed, decayed, or otherwise compromised • 10-49% of the crown is dead	Tree has any of the following: • Tree infected with canker rot fungus (see species in cover type chapters) • Canker affects >50% of the stem's circumference • Butternut canker affects >20% of combined circumference of the stem and root collar • White pine blister rust canker located where stem failure would cause a loss of >50% of the crown • Horizontal crack on a canker's face • Open crack on main stem is in contact with another defect, such as decay, a canker, or a weak union (V-shaped) • Crack goes completely through the stem or is open (bark and wood fibers split) for >5' of length • Two open cracks occur on the same stem segment • Cavity and associated decay affects >40% of the stem's cross-section • Decay in main stem results in <1" of sound wood for every 6" in diameter (2" for every 6" if a cavity is present) • Leaning tree with horizontal crack, long vertical crack, or buckling wood on the underside of the tree • Leaning tree with recent root lifting • More than 33% of roots severed, decayed, or otherwise compromised • Signs of cambium miners, such as two-lined chestnut borer or bronze birch borer • >50% of the crown is dead • >75% of the leaves subnormal in size or abnormal in color (this does not include color changes caused by nutrient deficiencies, fungal leaf spots, or other causes where crown recovery is expected

	Good Vigor	**Moderate Vigor**	**Low Vigor**
Crown class	Dominant or codominant	Dominant, codominant, intermediate, or suppressed	Dominant, codominant, intermediate, or suppressed
Crown size	In hardwoods, a full concentric crown. In conifers, a good crown/length ratio.	In hardwoods, a ½-¾ full concentric crown. In conifers, a fair crown/length ratio.	In hardwoods, a concentric crown less than half full. In conifers, a poor crown/length ratio.
Crown condition	Good silhouette and healthy leaves.	Fair silhouette and fair leaf condition.	Poor silhouette, poor leaf condition, and many branch stubs on upper and middle bole (see high risk).
	Good Timber Quality	**Moderate Timber Quality**	**Poor Timber Quality**
Bole length and form	Good stem form. Useable length commensurate with site; dbh/length ratio good; no usable length stoppers; and slight crook or sweep will cut out. For hardwood sawtimber – potential for at least one 16' butt log of tree grade 2 or better.	Moderate stem form. Useable length fairly commensurate with site; dbh/length ratio fair; usable length stopper on upper bole; or moderate crook or sweep will not cut out.	Poor stem form. Useable length far short of the average for the site; dbh/length ratio poor; permanently sub-merchantable in length; or heavy crook or sweep will not cut out.
Defect	Effects of defects on timber quality vary significantly, depending on the type and severity of a defect, tree species, and site factors. Some forest type chapters specify species specific indicators of timber quality; for example, the Northern Hardwood chapter includes information about the effects of defects on timber quality (40-66 to 40-71).		

Table 24.6 Recommendations for tree and snag retention in managed stands

Recommendations:

- Even-aged rotations
  - Retain ≥3 (if available), preferably large, snags per acre.
  - Retain reserve trees and/or patches at 5-15% crown cover or stand area, including large vigorous trees, mast trees, and cavity trees. Reserve tree retention is a generally recommended silvicultural practice for stands ≥10 acres. It is encouraged in smaller stands, but operational, shading, and other biological issues may limit application.
- Even-aged intermediate treatments
  - Retain ≥3 (if available), preferably large, snags per acre.
  - Retain ≥3 (if available), preferably large, cavity trees per acre.
  - Retain ≥3 (if available), preferably large, mast trees per acre.
  - If previously established, manage reserve trees and patches. Management may include timber harvesting or passive retention. Consider retaining ≥3 trees per acre to develop into large, old trees and to complete their natural lifespan. These trees may also satisfy cavity and mast tree recommendations. These trees will often become large snags and coarse woody debris.
- Uneven-aged systems
  - Retain ≥3 (if available), preferably large, snags per acre.
  - Retain ≥3 (if available), preferably large, cavity trees per acre.
  - Retain ≥3 (if available), preferably large, mast trees per acre.
  - Consider retaining ≥3 trees per acre to develop into large, old trees and to complete their natural lifespan. These trees may also satisfy cavity and mast tree recommendations. These trees will often become large snags and coarse woody debris.

When applying retention recommendations, be sure to consider:

- Individual trees can provide multiple benefits and fulfill the intent of more than one of the above recommendations. For example, three large oak trees with cavities could satisfy the mast tree and cavity tree recommendations, as well as the large, old tree consideration.
- Retention of both vigorous and decadent trees will provide an array of benefits.
- In general, species diversity is encouraged when selecting trees to retain.
- Large trees and snags are >12 inches dbh, and preferably >18 inches dbh.
- Trees retained can be scattered uniformly throughout a stand or irregularly dispersed, as single trees, groups, and patches. The general recommended strategy is to retain irregularly distributed patches along with scattered groups and individuals.
- Retention in aggregated patches generally provides the most benefits for wildlife and biodiversity. Also, patches retained can satisfy multiple benefits; for example, at stand rotation, an internal or adjacent unharvested buffer along a stream (RMZ) could provide a portion of reserve tree retention as well satisfy BMP (water quality) recommendations. Patches should be >0.1 acres and generally <2.0 acres, but can be larger; reserve tree patches, particularly large ones, should be documented as retention patches.
- Harvesting of reserve trees may occur in the future or may be foregone to achieve other benefits. Retain reserve trees for at least one-half the minimum rotation age of the new stand (e.g. retain reserve trees at least 20-25 years if regenerating aspen). Consider retaining some trees to develop into large, old trees and to complete their natural lifespan; these trees will often become large cavity trees, snags, and coarse woody debris.
- Retain as many snags as possible. Retention of snag diversity (species and size) can potentially provide the greatest array of benefits. Snags that are determined to be a threat to human safety can be cut and retained on site as coarse woody debris.
- Clearly designate, in writing and/or by marking, which trees should be retained prior to any cutting operations.