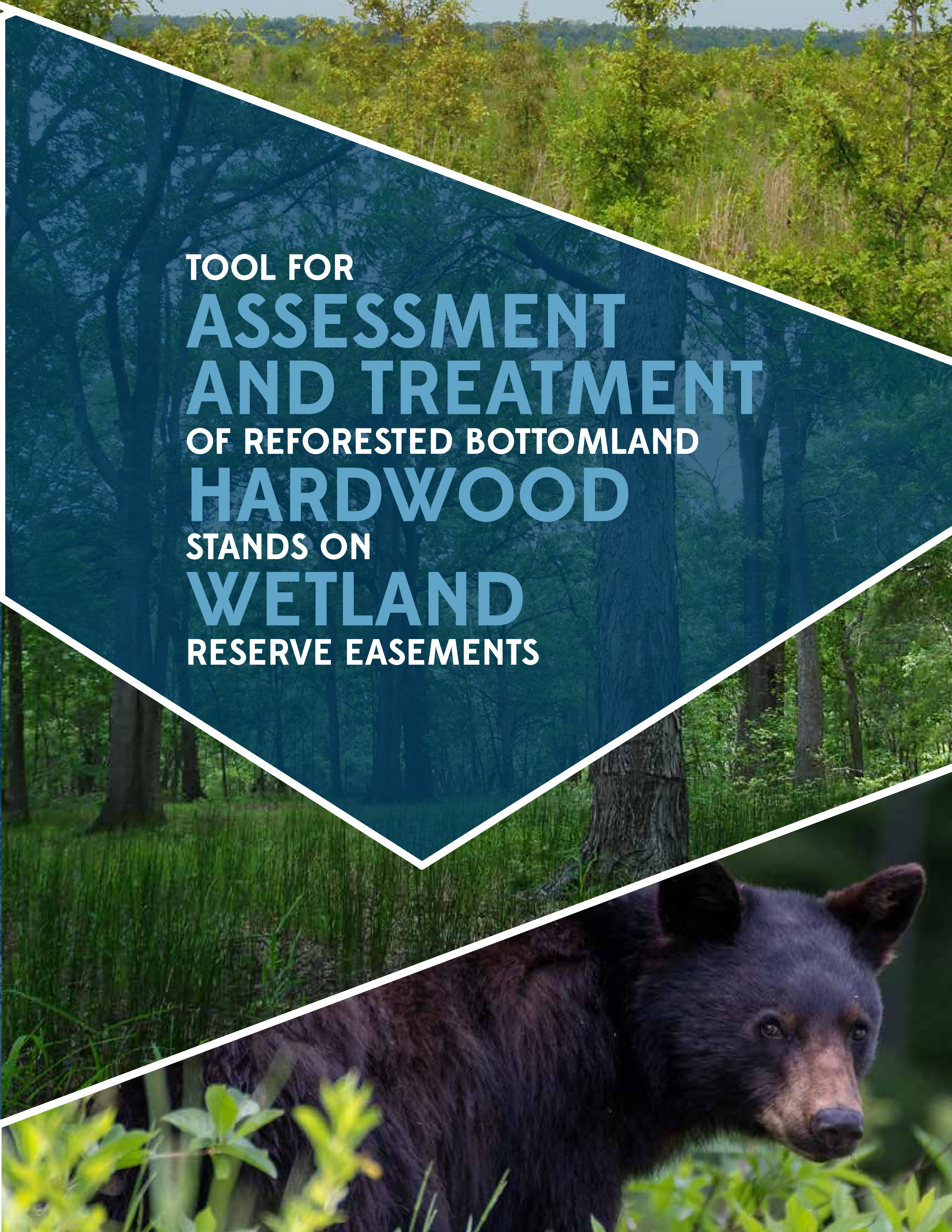
TOOL FOR ASSESSMENT AND TREATMENT OF REFORESTED BOTTOMLAND HARDWOOD STANDS ON WETLAND RESERVE EASEMENTS



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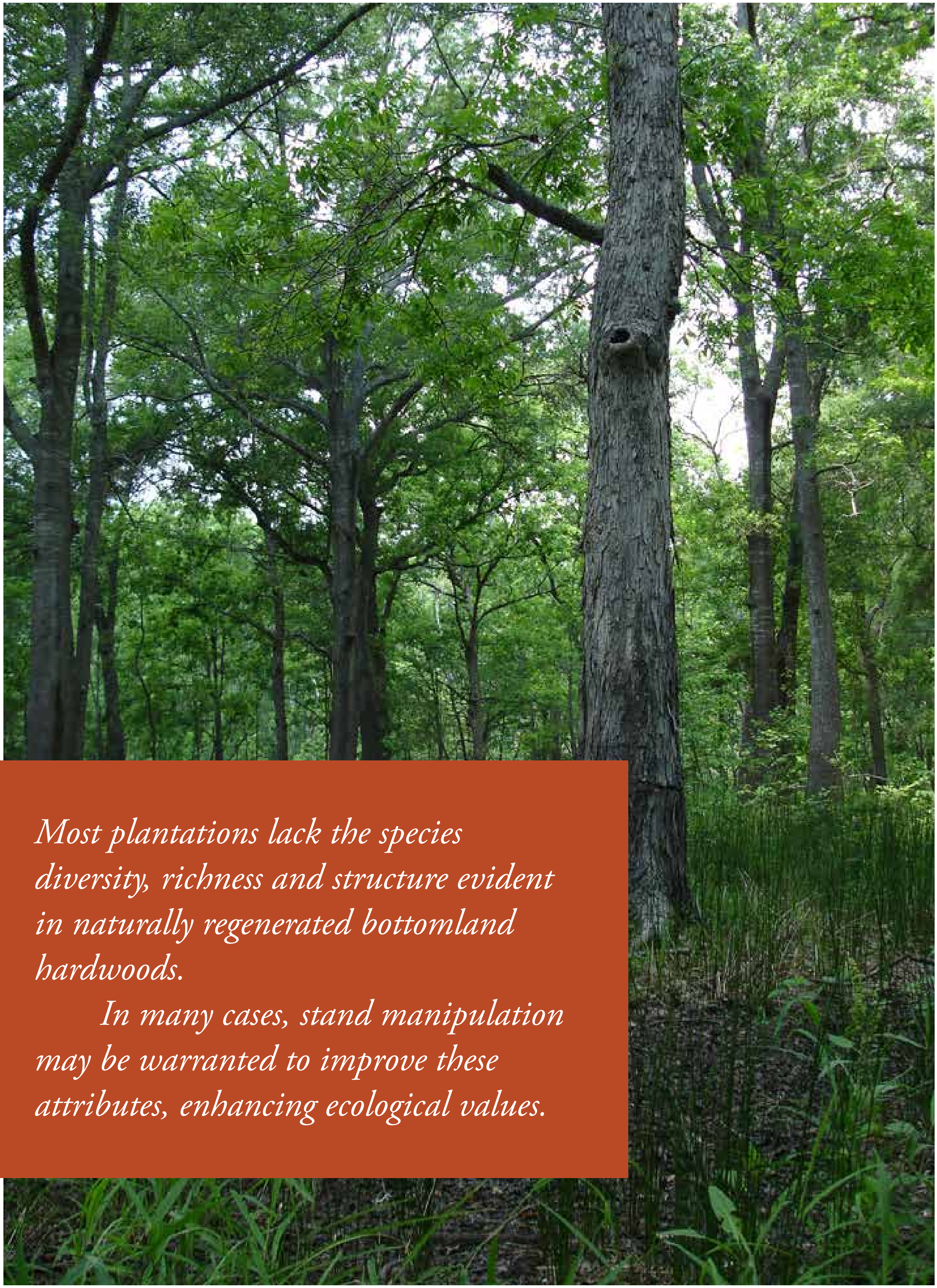

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PURPOSE OF DOCUMENT

This document was developed by a working group of the Tri-state Conservation Partnership (TCP) at the request of the Natural Resources Conservation Service (NRCS) in Arkansas, Louisiana and Mississippi. It is intended to assist the NRCS in addressing first entry treatment decisions and support compatible use agreement administration for bottomland hardwood plantations on Wetland Reserve Easements (WRE) in the three states.

The TCP is a collaborative effort chartered by the Lower Mississippi Valley Joint Venture and guided by a steering committee comprised of representatives from NRCS and conservation partners in Arkansas, Louisiana and Mississippi. Working groups are established through support of both the Arkansas Mississippi Alluvial Valley (MAV) and Louisiana/Mississippi MAV Conservation Delivery Networks to address specific priorities identified by the TCP steering committee. The WRE Forest Management Working Group participants are listed in Appendix 1.

Young BHW Plantation

INTRODUCTION

The great success of the Wetlands Reserve Program (now Agricultural Conservation Easement Program-Wetland Reserve Easements or ACEP-WRE) has resulted in a MAV of AR, LA and MS, that is replete with young developing bottomland hardwood (BHW) plantations, many of which have reached or are approaching the stem exclusion phase of forest development. These restored BHW plantations are dynamic and develop through multiple seral stages. They generally begin as grassy, herbaceous habitats, and then develop into shrub/scrub, and eventually progress into young forests. As succession advances, canopy closure occurs and understory vegetation becomes sparse. These conditions often persist until competition induced mortality occurs or the stand incurs catastrophic changes, such as wind-throw. Most plantations lack the species diversity, richness and structure evident in naturally regenerated bottomland hardwoods. In many cases, stand manipulation may be warranted to improve these attributes, enhancing ecological values. Prescribed treatments within these developing stands may also be necessary to ensure program goals are achieved. Objectives of ACEP-WRE are to protect, restore and enhance the functions and values of wetland ecosystems to attain the following:

1. Habitat for migratory birds and other wetland-dependent wildlife, including endangered or threatened species of concern.
2. Protection and improvement of water quality

3. Attenuation of floodwater
4. Recharge of ground water
5. Protection and enhancement of open space and aesthetic quality
6. Carbon sequestration
7. Protection of native flora and fauna contributing to the Nation's natural heritage
8. Contribution to educational and scientific scholarship

The first entry treatment recommendations provided in this document are intended to support NRCS natural resource professionals and cooperating conservation partners with addressing wildlife habitat concerns in a manner which is compatible with or furthers ACEP-WRE priority wildlife and other objectives. In addressing these objectives, when active management is determined to be appropriate, it is recommended stands be manipulated with the primary goal of creating desired forest conditions for wildlife (DFCW), such as increasing complexity of forest structure and diversity, as described by LMVJV Forest Resource Conservation Working Group (2007).

Photo by Bill Stripling

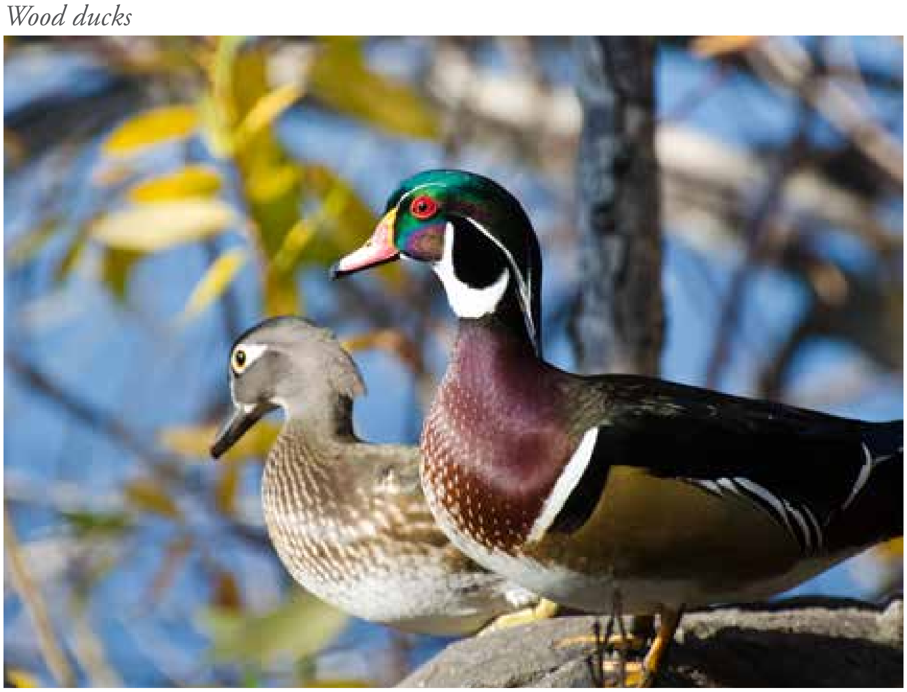
Prothonotary warbler

The goal should be to create or enhance stand conditions that meet the ecological needs of WRE priority wildlife, while maintaining a sustainable yield of forest products.

Stand condition, along with WRE and landowner management objectives, will determine timing and type of treatment used during the first stand entry. Effects of treatment, both short-term and long-term, will be directly related to timing and methodology of the manipulation. Trees may be removed at any stage of stand development however, commercial harvests, wherein the sale of forest products financially supports a prescribed treatment, are often the most feasible option. The goal should be to create or enhance stand conditions that meet the ecological needs of WRE priority wildlife, while maintaining a sustainable yield of forest products. This approach provides a cost-effective means of accomplishing habitat management whereby DFCW can be created or enhanced in an economically viable manner for most WRE landowners. Overly intensive or premature treatment of developing reforested stands generally should not be prescribed if the result is significant reduction in future silvicultural treatment options. Additionally, such treatments may significantly reduce flexibility in long-term management alternatives. Therefore, the following recommendations focus on developing forest management decisions which allow for more traditional, long-term, commercially based treatment methods. There are less frequent instances however, in which some form of stand manipulation is desired or warranted but commercial treatment methods are infeasible (e.g., absence of local forest products market or stands with abnormally high stem densities requiring much longer development periods before becoming commercially viable). In such circumstances, utilizing non-commercial treatment methods may be acceptable to achieve desired habitat objectives and to improve stand development toward the first commercial thinning treatment. A summary of non-commercial treatment alternatives is included in Appendix 2.

Forest stand development on restored easements can occur rapidly and habitat conditions may warrant manipulation relatively early in the life of the stand. Since wildlife habitat is a primary objective of the WRE program, BHW plantations may benefit from evaluation for possible first entry treatments between the ages of 15 and 25 years. An important first step in evaluating management need is assessing habitat deficiencies and factors limiting stand level growth potential and then taking corrective action if treatment is warranted. Various indicators and stand conditions may be used to determine if, when and how treatments should be administered. Currently, few specific silvicultural prescriptions exist to guide young bottomland stand development towards desired stand conditions (Meadows 1996) or to promote wildlife habitat. However, Goelz (1995) and Goelz and Meadows (1997) provide timber production stocking recommendations for even-aged stands that serve as a foundation for guiding management decisions. Their recommendations are based on hypothetical stocking levels provided by Putnam et al. (1960) for bottomland hardwood stands, but residual stocking levels in such stands have received limited experimental evaluation (Goelz and Meadows 1997). However, while evaluating habitat conditions, wildlife resource managers have observed similarities in the "apparent need for thinning" based on habitat conditions and the guidelines presented in Goelz and Meadows stocking guide. As such, use of the stocking guide is advocated as an underlying foundation in stand evaluation. Although in many situations the guide may be used as a "stand-alone" decision tool for identifying desired stocking objectives within a given stand, for the broader wildlife habitat management focus of this document, consideration of additional stand and habitat variables are recommended as well.

Wood ducks



TREATMENT INDICATORS AND STAND CONDITIONS

It is recommended that managers utilize three indicators for evaluating BHW plantations to determine if they should be treated:

1. Understory Index,
2. Live Crown Ratio (LCR) of Co-dominant Trees and
3. Stocking Level (as described in Goelz and Meadows 1997).

The decision of how to design treatments should be guided by stand conditions, including species composition, planting density, survival rates, clear bole length and site variables such as soils and hydrology. As managers gain familiarity with the recommended evaluation methods, basic information needed to assess stand conditions may be gathered anecdotally as part of the initial stand inspection and decision-making process. It should be recognized, in conducting an initial stand assessment, there may be instances when habitat conditions appear to warrant manipulation, while the indicators do not clearly suggest the stand is ready for treatment. Approaches to address these situations are presented in the *Developing Harvest Prescriptions* section as well as within the Decision Matrix (Appendix 3). General threshold values are presented for each indicator used to assess stands. However, these are only intended to be used as guidelines to support development of sound treatment decisions and may include exceptions.

In some cases, it may be desirable to postpone treatment of overstocked stands (or portions of stands), "pre-maturely" treat understocked stands, or consider creative treatment approaches to address special management concerns or objectives. For example, if desired habitat conditions appear deficient in a stand and indicators point to treatment, but the stand comprises a relatively small portion of a larger landscape already supporting desired habitat conditions, delaying treatment may be the most appropriate alternative. In its current condition and position in the landscape, the stand may be providing unique resources or habitat that is generally lacking. Conversely, there may be situations in which all indicators point to the need for treatment and it may be prudent to treat the stand regardless of landscape conditions, in order to meet objectives that support stand health and long-term WRE habitat management goals. While stand assessment recommendations provided herein are intended to assist land managers in making treatment decisions, these examples demonstrate there is not a single treatment method or prescription that will fit all first-entry stand conditions. Treatment decisions should always be weighed against habitat management objectives and their relationship to the broader landscape.

INDICATOR DEFINITIONS AND THRESHOLD VALUES

Understory Index

There is a strong inverse correlation between stand stocking levels and the density (or coverage) of understory vegetation. A similar relationship exists between stocking levels and overall stand structure, including gaps and vegetative layering. For example, a densely stocked stand will generally contain a sparse, poorly developed understory while a stand with lower stocking, numerous canopy gaps and openings will generally contain greater structural diversity and a more developed understory. Absence of a well-developed understory does not always indicate the stand is ready for thinning, but the presence of such an understory is generally a good indicator it is not.

The understory index should be used during the growing season to evaluate volume/presence of flora from zero to approximately six feet in height. The index considers understory plant density and species diversity, along with plant types (e.g., herbaceous, woody, annual, perennial, vines, shrubs, grasses and forbs). Although ground cover (e.g., grasses or sedges) may be considered as part of the understory index, a well-developed understory, such as *Rubus* patches or various woody vines, may have little ground cover. In

contrast, a heavy ground cover of shade tolerant sedge or grass in the absence of woody species is not considered a well-developed understory. Such monotypic grass or sedge communities may be rated as low or very low when utilizing this initial indexing approach.

Upon initial evaluation of a stand, both the Understory Index and LCR should be conducted simultaneously. Based on field observations, an understory index score can be calculated and used to help determine if treatment may or may not be warranted. If the understory index score is less than 220 (assuming it is due to low light conditions and not flooding), there is a strong probability the stand is stocked sufficiently to warrant thinning. An understory index greater than 320 reflects a robust understory and stocking probably is too low to justify thinning. Between these thresholds and in conjunction with LCR estimate, if a decision to treat the stand is not clear, an evaluation of stocking is advised.

Live Crown Ratio

LCR is indicative of tree vigor and is often related to intensity of competition in the upper crown classes. It is estimated as the proportion, expressed as a percent, of healthy foliage relative to a tree's total height. **LCR estimates should only be made from co-dominant trees,** from the point where the concentration of canopy foliage actually starts, not at the lowest live limb.

Average LCR may be used at the stand level as a quick, relatively simple index for identifying stands with either very high or very low levels of stocking,

TABLE 1: Understory Index Data Collection Method

		PLOT/POINT												
INDEX	VALUE	1	2	3	4	5	6	7	8	9	10	% OF POINTS	COMPUTATION	SCORE
VERY LOW	1	X										10	10 (1)	10
LOW	2		X	X								20	20 (2)	40
MEDIUM	3				X	X	X				X	40	40 (3)	120
HIGH	4							X		X		20	20 (4)	80
VERY HIGH	5								X			10	10 (5)	50
											TOTAL	100		300

UNDERSTORY INDEX DESCRIPTIONS

VERY LOW = 1
A general absence of understory plants throughout, or a monotypic ground cover of sedges or grasses, with little else present.

LOW = 2
Generally sparse understory but may include small patches of denser vegetation.

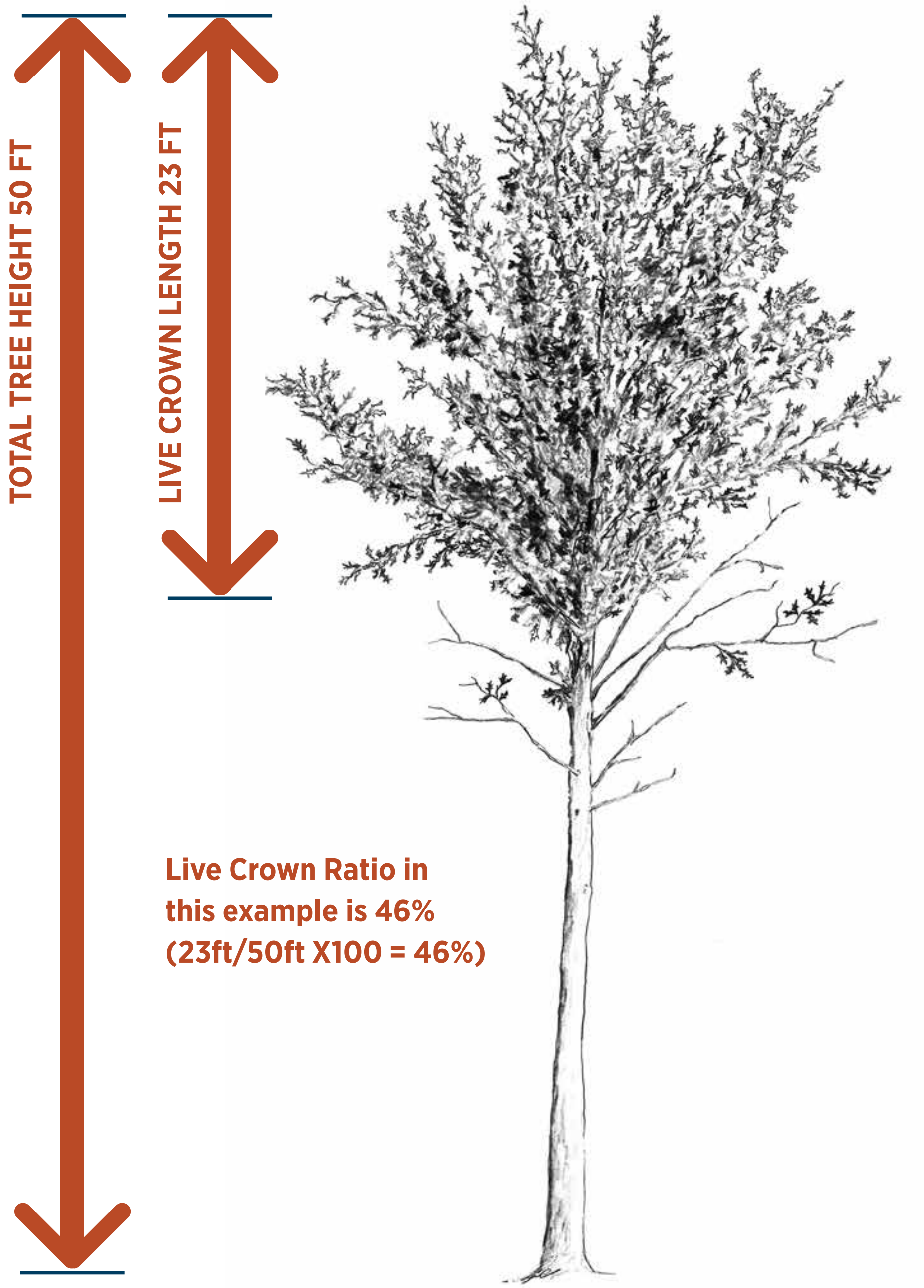
MEDIUM = 3
Significant presence and diversity of plant types but access generally un-impeded. Areas of low or very low density may be frequently interspersed.

HIGH = 4
Dense vegetation over majority of area but may be interspersed with areas of medium, low, or very low understory. Access somewhat impeded but not precluded.

VERY HIGH = 5
Consistent occurrence of robust vegetation. Access is difficult.

but it is not recommended as a stand-alone decision metric. In utilizing this metric, be aware that stocking being equal, LCR can be influenced by shade tolerance and/or predisposition to self-pruning of each species, making its usefulness as an indicator most applicable in more monotypic, uniformly stocked stands.

Stands with an average LCR below 40 percent (for most BHW species) are generally at or near full stocking, diameter growth is retarded, and canopy closure does not permit enough light through the canopy for understory vegetation to persist. For these stands, treatment is generally warranted. Conversely, when LCR of co-dominant trees is greater than 70 percent, the stand should not be thinned. For stands between these extremes, managers should refer to other indicators/measures (see Stocking below). **Note**: If stands are primarily cypress, willow oak and overcup oak, use 50 and 80 percent as decision points; for ash and cottonwood dominant stands use 30 and 60 percent.



When estimating percent live crown, you should not consider scattered, individual limbs with sparse green foliage below the tree's primary crown.

Stocking

Stocking is a quantitative measure of area occupied by trees within a stand. It is generally expressed as a percentage based on basal area (BA), number of trees, volume, or other criteria, on a per acre basis. Stocking is generally separated into the following levels:

a. Fully stocked stands – Stands in which all growing space is effectively occupied but still allow ample room for development of crop trees.

b. Overstocked stands – Stands in which growing space is so completely utilized that growth rates of many trees, including dominants, are being negatively influenced.

c. Understocked stands – Stands in which growing space is not effectively occupied by crop trees.

Goelz (1995) presents a useful bottomland hardwood stocking guide to aid in determining stand density management for timber production. In the stocking guide (Figure 1), the A-line represents 100 percent stocking and can be used to identify stands which may benefit from thinning. Goelz offers the B-line as a suggested residual stocking after thinning for optimal timber production. Additionally, Goelz and Meadows (1997) offer alternatives which may be appropriate for other management objectives. One such alternative is the C-10 line (Figure 1), which implies that by reducing stocking to the C-10 level, it would take 10 years for a stand to "recover" to the B-line (Goelz 1997).

When DFCW is a primary management objective, it may be acceptable to manipulate a stand before it reaches 100 percent stocking. Young, even-aged plantations with 70-80 percent stocking often exhibit deficiencies in understory vegetation, canopy gaps, and structural diversity. Table 2 can be used to evaluate if current stocking levels indicate need for stand treatment. This table applies to stands which can meet reasonable expectations of future merchantability for a given site and species. Stands comprised of species not well suited to current site conditions or stands which developed with low stem density may warrant some type of "rehabilitation" treatment, despite not meeting stocking levels that normally "trigger" manipulation. In such cases, corrective action may include but is not limited to, species conversion through patch cuts designed to release desirable natural regeneration and/or by incorporating additional seedlings within patch cuts.

TABLE 2: Relationship between percent stocking and treatment decisions

STOCKING LEVEL	TREATMENT DECISION
>80%	Warranted
70 - 80%	Warranted, but optional
60 - 70%	Likely not warranted
<60%	Not warranted

As an additional reference, Table 3 provides an interpretation of Figure 1 to visually demonstrate the relationship between percent removal (e.g. 50-60%, 40-50%, etc.) and degree of thinning intensity (i.e. light, moderate and heavy). It is not intended as an exhaustive list of alternatives for all situations.

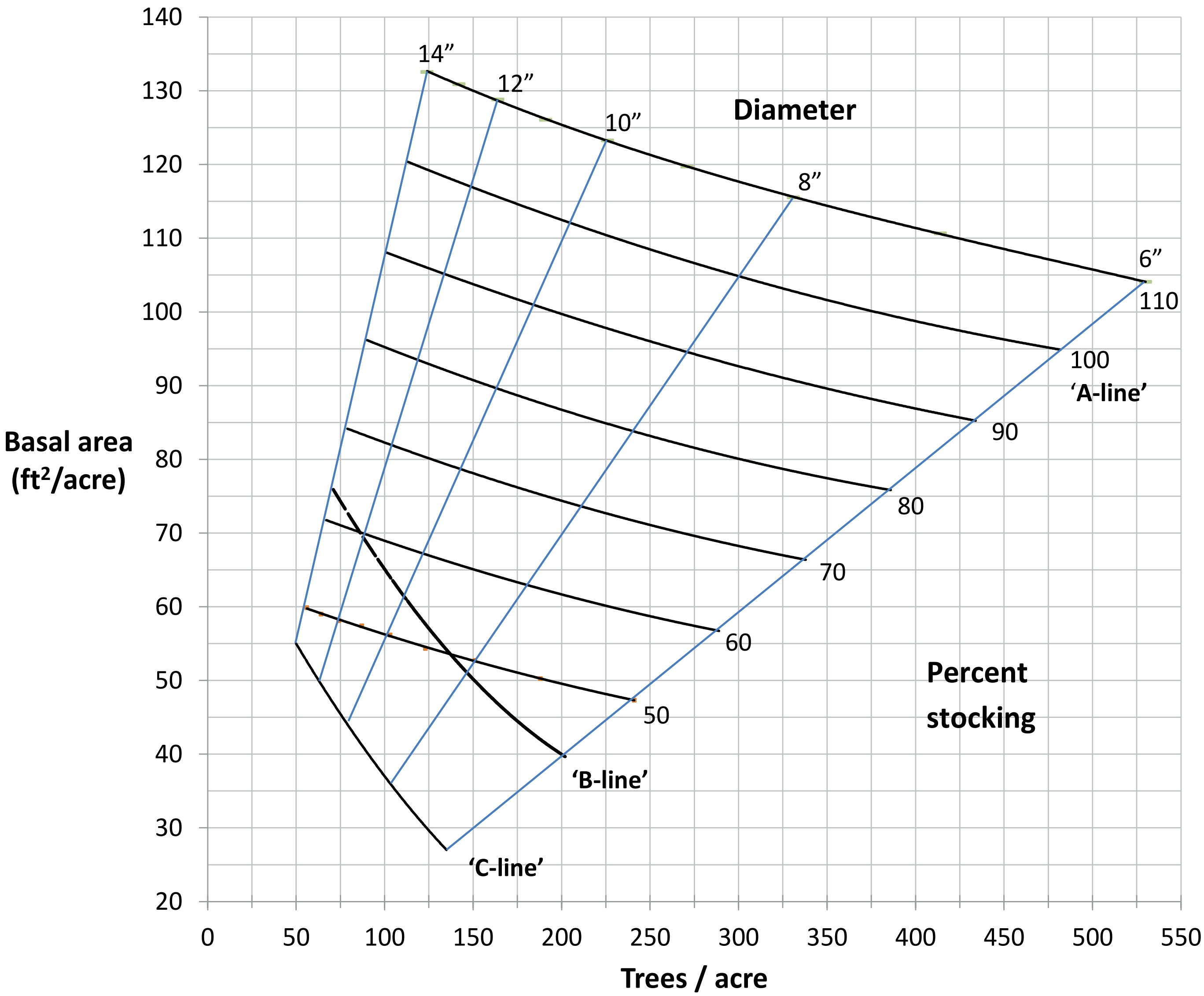
EVALUATING PLANTATIONS

Stocking is by far the most important of the three indicators to consider when determining both ultimate need for and level of treatment within a stand, as it significantly and inversely effects both understory development and LCR. In many cases, stand level stocking could be used alone to determine if treatment is warranted. However, when managers first visually assess stands, the most obvious and telling parameters are condition of the understory plant community and clear bole length or degree of self-pruning as indicated by LCR. Therefore, understory and LCR indicators are intended to be most useful in initially identifying stands at extremes of stocking, leading to an easy decision to delay treatment and prevent the need for the additional work required in conducting an actual stand inventory. If these two indicators suggest the stand is overstocked or indicators are not adequately conclusive to determine if no treatment is warranted, then conducting a fixed-area inventory is recommended to further evaluate stand stocking. Conversely, if the stand is clearly understocked and thinning is not warranted, conducting an inventory is unnecessary and the stand should be revaluated in 3 – 5 years. A systematic approach to evaluating stands is provided below, along with a Decision Matrix (Appendix 3) to help guide decision making.

Step One: Point Cruise and Cursory Observation

Utilize the tally sheet provided in Appendix 4 to conduct a simple point cruise to evaluate understory and LCR, as well as to determine prevalence of invasive species (Chinese tallow tree, autumn olive, privet, etc.). After conducting the point cruise, refer to the Decision Matrix to evaluate data collection results and determine if no treatment is warranted or if it is necessary to conduct an inventory (see Step 2) to ascertain actual stocking levels. Experienced managers may be comfortable using their judgement to make these assessments, precluding the need for collecting hard data. In some instances,

FIGURE 1: Stocking guide for young bottomland hardwood stands with quadratic mean diameters between 6-14 inches.* Percent stocking is a function of basal area and trees/acre. Desirable stocking levels are indicated, as suggested by Putnam et al. (1960) and Goelz (1995, 1997). (B. Frey, adapted using equations from Goelz (1995) and Goelz (1997)).



**Note: Quadratic Mean Diameter (QMD) is commonly used in forestry research to provide the most statistically accurate diameter estimate. However, statistical difference between QMD and arithmetic mean diameter (avg. DBH) has been shown to be very small in stands with relatively small and narrow range of diameters (Curtis and Marshall 2000, Technical Note), e.g. developing WRE BHW plantations. Therefore, in utilizing these recommendations, substituting DBH in place of QMD will provide sufficient accuracy to develop harvest prescriptions.*

TABLE 3: Thinning intensity alternatives and their relationship to recommended B-line and C10-line residual stocking (Figure 1) based on initial stocking level and QMD. These relationships assume average DBH remains similar after thinning. If favoring larger diameters for retention, actual residual stocking will be slightly higher since average DBH will be somewhat increased.

	INITIAL STOCKING																			
	70%					80%					90%					100%				
	INITIAL		RELATIONSHIP TO RECOMMENDED RESIDUAL STOCKING LINES IF CUT BY (X)%			INITIAL		RELATIONSHIP TO RECOMMENDED RESIDUAL STOCKING LINES IF CUT BY (X)%			INITIAL		RELATIONSHIP TO RECOMMENDED RESIDUAL STOCKING LINES IF CUT BY (X)%			INITIAL		RELATIONSHIP TO RECOMMENDED RESIDUAL STOCKING LINES IF CUT BY (X)%		
QMD	TPA	BA	50%	55%	60%	TPA	BA	50%	55%	60%	TPA	BA	50%	55%	60%	TPA	BA	50%	55%	60%
5”	448	61	B-	B/C	C+	512	70	B	B-	B/C	576	79	B+	B	B-	640	87	B++	B+	B
6”	337	66	B/C	C+	C	386	76	B-	B/C	C+	434	85	B+	B	B/C	482	95	B++	B+	B
7”	263	70	C+	C	C-	301	80	B/C	C+	C	338	90	B	B/C	C+	376	100	B+	B	B/C
8”	211	73	C	C-	C--	241	84	B/C	C+	C-	271	94	B-	B/C	C+	301	105	B	B-	B/C

	INITIAL STOCKING																			
	70%					80%					90%					100%				
	INITIAL		RELATIONSHIP TO RECOMMENDED RESIDUAL STOCKING LINES IF CUT BY (X)%			INITIAL		RELATIONSHIP TO RECOMMENDED RESIDUAL STOCKING LINES IF CUT BY (X)%			INITIAL		RELATIONSHIP TO RECOMMENDED RESIDUAL STOCKING LINES IF CUT BY (X)%			INITIAL		RELATIONSHIP TO RECOMMENDED RESIDUAL STOCKING LINES IF CUT BY (X)%		
QMD	TPA	BA	40%	45%	50%	TPA	BA	40%	45%	50%	TPA	BA	40%	45%	50%	TPA	BA	40%	45%	50%
8”	211	73	B/C	C+	C	241	84	B	B-	B/C	271	94	B+	B	B-	301	105	N/A	B+	B
9”	172	76	C+	C	C	197	87	B-	B/C	C+	222	98	B+	B-	B/C	246	109	B++	B+	B-
10”	144	78	C+	C	C-	164	89	B/C	C+	C	185	101	B	B-	C+	205	112	B+	B	B-
11”	121	80	C	C-	C--	139	92	B/C	C+	C	156	103	B-	B/C	C+	173	114	B	B-	B/C

	INITIAL STOCKING																			
	70%					80%					90%					100%				
	INITIAL		RELATIONSHIP TO RECOMMENDED RESIDUAL STOCKING LINES IF CUT BY (X)%			INITIAL		RELATIONSHIP TO RECOMMENDED RESIDUAL STOCKING LINES IF CUT BY (X)%			INITIAL		RELATIONSHIP TO RECOMMENDED RESIDUAL STOCKING LINES IF CUT BY (X)%			INITIAL		RELATIONSHIP TO RECOMMENDED RESIDUAL STOCKING LINES IF CUT BY (X)%		
QMD	TPA	BA	30%	35%	40%	TPA	BA	30%	35%	40%	TPA	BA	30%	35%	40%	TPA	BA	30%	35%	40%
11”	121	80	B/C	C+	C	139	92	B	B-	B/C	156	103	B+	B	B-	173	114	B++	B+	B
12”	104	82	B/C	C+	C	119	93	B-	B/C	C+	134	105	B+	B	B-	149	117	B++	B+	B
13”	90	83	C+	C	C-	103	95	B-	B/C	C+	116	107	B	B-	B/C	129	119	B++	B+	B
14”	79	84	C+	C	C-	90	96	B/C	C+	C+	101	108	B	B-	B/C	112	120	B+	B	B-

**Refer to Harvest Intensity (Table 4) for treatment alternatives. For most applications, 4th or 5th-row removal for access is the recommended approach.*

LEGEND

	B++	B+	B	B-	B/C	C+	C	C-	C--
POSITION RELATIVE TO B-LINE AND C10-LINE	above B-line	slightly above B-line	~at B-line	just below B-line	midway of B&C-line	just above C-line	~at C-line	just below C-line	below C-line
THINNING INTENSITY*	light	light	light	light	moderate	moderate	heavy	heavy	heavy

a manager may choose to skip the point cruise and proceed directly to conducting a fixed-area inventory.

In conducting a point cruise, it is important to gather data around a sufficient number of point locations throughout the entire stand in order to gain an adequate perspective on stand conditions. Though there is no absolute standard for conducting the point cruise, it is recommended to assess a minimum of 10 points for small, uniform stands <30 acres and 1 point per 3 acres up to 50 ac (i.e., 17 points for a 50-ac stand; 13 for a 40 ac stand, etc.). Stands greater than 50 acres probably should be stratified, bringing each unit down to less than 50 acres and subject to the 1 point per 3 acres rule. Homogeneous stands over 50 acres may be indexed more conservatively (e.g., between 10 and 20 points in 75 to 100+ acre stands depending upon observed understory condition – homogeneity vs. diversity).

It is important to note that evaluating understory and LCR will likely be difficult during winter months and it is recommended this data be collected during the growing season or shortly thereafter before leaf fall. Note also that evaluating LCR from directly below a tree often results in an underestimation. One technique to assist with estimation is to stand back far enough from the tree to be able to visually divide the tree in half and if necessary, in half again (quarters). Evaluating LCR in relation to half or quarter tree increments typically increases accuracy of estimation.

If initial understory index evaluation and/or point cruise determines one or more exotic invasive species are prevalent in the stand, any prescribed stand management activities should be postponed to allow for treatment of invasive(s), rather than facilitate spread throughout the stand. Chinese tallow-tree (*Triadica sebifera*), Chinese privet (*Ligustrum sinense*) and trifoliate orange (*Poncirus trifoliata*) will generally be the most problematic invasive plant species within timber stands in the MAV. If identified, all stems of these species should be treated within the affected area. Sites containing seed-bearing individuals will likely take a minimum of two, but most likely three successive years of treatment to control prior to resuming timber harvest. First year treatment prioritizes removal of overstory and seed-bearing trees/shrubs, while successive treatments are necessary to control seeds that typically sprout prolifically in the understory following canopy disturbance. Herbicide application will likely be the most suitable treatment method in most situations, but mechanical treatment followed by subsequent herbicide applications could be a viable option in some cases.

Karan A. Rawlins, Univ. of Georgia, Bugwood.org

Chinese Privet

James H. Miller, USDA Forest Service, Bugwood.org

Chinese Tallowtree

John D. Byrd, Mississippi State University, Bugwood.org

Trifoliate Orange

Step Two: Fixed-area Inventory

The primary purpose of conducting a fixed-area inventory is to document stand stocking (number of trees per acre [TPA] and average stem diameter) and species composition. This may be best accomplished utilizing a fixed-area plot sampling method. After completing an inventory, refer to the Decision Matrix (Appendix 3) to determine if stand treatment is warranted.

Steps for completing an inventory include:

1. **Stratification**: The objective of stratification is to identify and delineate potential treatment units within a stand which include areas of relatively uniform species composition, stand density and average DBH. When conducting an inventory, field notes should be made and/or areas mapped to denote significant changes in any of these variables. Stratification, where appropriate, will facilitate and strengthen data analysis and lead to a more effective treatment prescription. For example, changes in elevation or soil type within a reforestation planting unit can result in variations in stand density and/or growth rate. This may result in portions of the planting unit achieving stocking levels which warrant treatment while other areas have not, thus necessitating stratification.

2. **Plot Size and Frequency**: An intensive inventory is generally not required. A cruise providing a reasonable average estimate is adequate. In most BHW plantations, an inventory of 1 to 2 percent, using plots from 1/100th to 1/20th acre is recommended. For a given cruise intensity, using a smaller plot size requires more plots, resulting in better distribution throughout the stand. Therefore, for small acreages or heterogeneous conditions, the smaller plots may be better; if larger plots are used, the cruise percent must be increased to insure adequate plot distribution. In larger stands or where stem density is low, larger plots may be preferred. For each 10 acres sampled, a one percent inventory requires ten 1/100th acre plots, five 1/50th acre plots or two 1/20th acre plots. For example, a 40-acre stand would require forty 1/100th acre plots, twenty 1/50th acre plots or eight 1/20th acre plots. Sampling at two percent intensity can be achieved by doubling the number of plots.

3. **Data Collection**:

   Tree Sampling: Tally trees (species and DBH) in intermediate, co-dominate, and dominant crown classes (Appendix 5a). Trees with over-topped or suppressed crowns contribute relatively little to stand basal area. However, their occurrence should be noted, particularly when comprised of species generally lacking in the upper crown classes.

   Regeneration: As considered here, regeneration is tree seedlings or saplings occurring in the understory or mid-story. In developing BHW plantations, advanced reproduction is more important with regard to increasing species richness rather than stem density, thus it is not always necessary to quantify. Stands sufficiently stocked and developed to warrant evaluation for potential treatment, generally do not need to be regenerated. However, in the interest of increasing species diversity in stands with a more monotypic overstory, presence of advanced reproduction of other desirable species should be noted. Environmental conditions under closed canopied, oak-dominated stands are generally not favorable for establishment and/or development of seedlings. However, canopy gaps or site variations may result in occurrence of patches of non-oak regeneration which may influence the type of treatment prescribed (e.g. incorporating group removals or patch cuts intended to release desirable regeneration). Density and competitive position of regeneration should be considered. Stems should be assigned to two broad size-classes; overtopped saplings > 6' in height effectively acting as a midstory, and seedlings in the understory. Estimating numbers for each size-class into broad ranges rather than precise counts should be sufficient and will expedite the inventory process. Rounding estimates into categories such as: none, 10/ac, 25/ac, 50/ac, 100/ac, 150/ac, 200/ac and 300+/ac will be sufficient for prescription development. Species should be noted but not necessarily quantified individually.

<u>Habitat Components and Other Conditions</u>: Factors other than stocking may not contribute significantly to the decision of whether or not to treat a stand but may influence how a treatment is administered to better target management objectives. Desirable habitat components such as vine-laden, broken-topped or senescing trees do not necessarily need to be quantified but should be noted. If they occur frequently throughout the treatment area, special consideration is generally not necessary to insure retention of significant numbers after harvest. However, if these desirable components are generally scarce, some portion may be retained by establishing periodic un-cut rows or no entry zones, establishing rules for avoidance by equipment operator, or identifying as "leave trees" with marking paint. Additional stand conditions which may influence harvest methodology may include:

a. Site Compatibility of Predominant Species - a preponderance of off-site tree species may steer managers to consider regenerating portions of the stand using groups or patch cuts.

b. Tree Growth/Performance - if stocking levels, crown condition or bark patterns indicate growth or health is substantially reduced, a general crown thinning, with or without groups, should be considered rather than groups or patch cuts alone.

c. Unique or Sensitive Areas – occurrence within treatment units may require modifying the harvest approach or avoiding treatment in these areas.

d. Clear Bole Length - if LCRs are relatively high but treatment is still warranted, light/conservative thinning may be prudent, with groups added to promote more enduring understory development.

e. Invasive Species (which should always be noted and documented in the inventory) - generally call for postponement of treatment until control of infestation is accomplished. Otherwise, an untreated buffer should be established.

A Fixed-area Inventory - Overstory Tally Sheet is included for field use in Appendix 5a. In addition, a Sample Fixed-area Inventory - Overstory Tally Sheet is provided in Appendix 5b

Factors other than stocking may not contribute significantly to the decision of whether or not to treat a stand but may influence how a treatment is administered to better target management objectives.

Active Plantation Thinning Operation

which contains sample calculations to assist with inventory data analysis.

Thinned Plantation - 3 Years Post Treatment

DEVELOPING HARVEST PRESCRIPTIONS

If it is determined treatment is warranted, a harvest prescription should be developed based on stand conditions and management objectives. Stand conditions can be highly variable. Metrics such as species richness in each stratum (i.e., understory, midstory, overstory), average tree diameter, diameter distribution, stocking levels and desirable components (cavities, vines etc.) can vary widely within stands. Information from the inventory, along with the Decision Matrix table included in Appendix 3, should be used to inform harvest prescriptions to ensure maintaining health, vigor and future merchantability of the stand.

Stand manipulation treatments generally call for removal of overstory trees, either through commercial or non-commercial means. Desired post treatment habitat response and conditions can be largely guided by controlling the intensity of tree removal, the arrangement of residual stems, and the selection criteria for either retained or removed trees.

1. **Intensity of Tree Removals**: Harvest intensity may be interpreted as percent reduction in stocking level. When applying general crown thinning, the stocking chart (Table 3) may be used as a guide to achieve desired intensity (e.g. heavy thin vs light thin). Though patch cuts and group removals reduce stand level stocking, they entail complete overstory removal and are better guided through area regulation (see Tree Removal Methods and Patterns). For example, if the prescription calls for crown thinning with periodic group removals, the desired thinning intensity should be applied to the area between well-defined group openings, and then prescribed proportions of complete overstory removal (i.e. groups) may be achieved by controlling size and frequency of openings.
2. **Arrangement of Residual Stems**: Residual stocking being equal, variations in spatial distribution of residual trees can create variability in the light environment, which may lead to greater and more diverse understory response. Inconsistencies in arrangement of stems (i.e., variations in size of canopy gaps) may also serve to facilitate crown stratification as well, by providing some individuals significantly more relief from competition and/or creating conditions which alternately favor shade-tolerant and shade-intolerant trees.
3. **Selection Criteria**: Random removals can be used to achieve some management objectives, but selective removal can have a greater impact on post-harvest conditions and future stand development. Removing trees randomly reduces basal area and stand density, thereby improving growth of residual trees and fostering some understory development, but it will not change the average tree diameter or favor desired species which are under-represented. An inherent objective is to shorten the time necessary for the restored site to become "mature" BHW. To more rapidly move the planted stand to a forest rich in site-adapted species, including large diameter trees, harvests guidelines should be established to selectively remove trees based on numerous criteria (e.g. species, diameter, bole quality, crown condition, etc.).

Habitat conditions generally warrant treatment before stands attain 100% stocking and manipulations are seldom prescribed in stands with only 60% stocking. Therefore, treatments will most often be applied in stands with 70% to 90% stocking levels. It is recommended that targeted residual stocking levels fall near or between the B-line and C-10 line (Figure 1). In order to achieve recommended residual stocking, stands with smaller average diameters must be reduced by a greater percent than stands of larger stems. For example, stands with an average DBH of 5”- 6” can be reduced 50%-60%, depending on their initial stocking, while stands with average DBH of 13”-14” only need reducing by 30%-40% (Table 3). These percentages can be applied to either stem density or BA if trees are selected without diameter bias, as random diameter removals will generally result in proportionately equal reductions in BA and stems per acre. However, it should be noted that favoring larger stems for retention removes a lesser proportion of BA, resulting in less reduction in stocking level than stem count.

For stands in which the average DBH and/or stocking level varies, but is not easily delineated on the ground, a good “rule-of-thumb” is to remove 50 percent of stems; this applies where average diameters range from 5” to 10” and stocking is 70%-90%. In applying this approach, the post-harvest stand will fall within recommended stocking range but intensity of removals will vary throughout the stand, which is both acceptable and often suggested. A harvest prescription may call for one cutting technique with very simple specifications or it may entail some combination of tree removal patterns and additional cutting “rules” that vary with changing conditions across the treatment area. Habitat treatment prescriptions may include the following decisions:

Habitat conditions generally warrant treatment before stands attain 100% stocking and manipulations are seldom prescribed in stands with only 60% stocking.

1. Will treatment be accomplished through mechanized commercial or non-commercial harvest methods.
2. Invasive control – method of treatment and length of time preceding further stand manipulations (harvests).
3. Tree removal patterns
    a. If thinning - what intensity (e.g., heavy, moderate or light)
    b. If groups are prescribed
    c. What are specifications (e.g., size, proportion of stand, location, etc).
4. Designation of access row frequency (e.g., every 4th or 5th or alternative approach where rows are not discernable).
5. Means to retain or increase species diversity (e.g., restrict harvest of certain species as a “rule”, mark trees, release overtopped advanced regeneration, etc.).
6. Tree selection criteria - will trees be favored by species, diameter, crown position, bole quality, habitat component, etc.

Photo by Bruce Beehler

Yellow-throated Warbler

7. Habitat components such as senescing, broken-topped, or vine-laden trees - is special consideration necessary to insure adequate numbers are retained.

Monotypic, uniformly stocked stands with easily identified rows present the simplest decisions and approaches to treatment. In such situations, operator select crown thinning favoring larger diameter trees for retention can be an effective, straightforward approach. Additional variations to enhance habitat diversity can also be incorporated by removing small groups of trees totaling some predetermined percentage of area (e.g., 5 to 10 percent of the stand or even higher [15 to 30%], if management objectives warrant), to create longer lasting canopy gaps scattered throughout the treated stand. In certain circumstances, group removal may be used as a single treatment method, e.g., younger stands where overall thinning may need to be delayed but canopy openings are desired to promote diversity of both habitat and tree species composition.

Mixed species stands with desirable composition are challenging due to differential growth rates of individual species. Simply favoring larger diameter trees may lead to bias against some species. It is recommended mixed-species stands be marked for timber sales rather than subject to operator selection. In any case, commercial or non-commercial treatments should not be strongly biased against certain species because species diversity is considered necessary to meet WRE program objectives. Prescriptions for mixed species stands should be developed in a manner that preserves species diversity and richness.

Plantations in which multiple species were used but planted separately in relatively monotypic strips or patches may result in alternating strips of well-stocked areas in "need of thinning" and strips which are not ready to be thinned due to differential growth and/or survival rates of each species. Viewed as a whole, the stand may have adequate understory and structural diversity, thus applying treatments in such stands should be largely based on relative proportion in each condition. If well-stocked strips would benefit from further self-pruning without substantially increased risk to health and vigor, it may be prudent to delay treatment.

Stands of larger diameter trees (i.e. 10" or greater) which developed under relatively low stem density conditions (e.g. 175 TPA) may be stocked in excess of 70 % and only seem to need thinning based on stocking level. However, such stands may be excessively limby, and for long-term management objectives, regenerating substantial portions of them may be a better decision than simply thinning. As always, landscape perspective is important and managers may accept retention of relatively small areas dominated by short-boled, limby trees, particularly if diverse in species and structure. Conversely, larger expanses of closed canopied, monotypic stands of trees with poor prospects for future merchantability may justify regeneration of plantations despite 20-30 years of growth.

Photo by Bill Stripling

Acadian Flycatcher

When developing the prescription, consideration should be given to the potential for coppice regeneration. It can be beneficial if developing a two-age stand is desired. Coppice is also often the primary source for midstory development following a treatment. However, vigorous coppice from stumps of planted trees may inhibit viability of seedlings as a source of regeneration, thereby reducing the potential to increase species diversity. Additionally, vigorous oak coppice can rapidly bring the stand right back to a shaded understory condition. It is also important to be aware of flood regimes in the area as flooding during the growing season can greatly reduce coppice sprouting and managers should use caution if counting on it as a source of regeneration.

Table 4 includes a variety of treatment options for removing 40 to 60 percent of stems in a stand and is provided to assist managers in meeting prescribed stocking reductions.

TABLE 4: Harvest Intensity - Percent removal of stems based on rate of access row removal and treatment within retention rows.

A	B	C	D	E	F
HARVEST INTENSITY - APPROXIMATE % STEMS REMOVED	ACCESS ROWS - ALL STEMS REMOVED	THINNED ROWS PER ACCESS ROW	UNTREATED ROWS PER ACCESS ROW	RATE OF TREE REMOVAL ON THINNED ROWS ADJACENT TO ACCESS ROW	RATE OF TREE REMOVAL ON ROWS ONCE REMOVED FROM ACCESS ROW
50	EVERY 3RD	2	0	1 OUT OF 4	N/A
55	EVERY 3RD	2	0	2 OUT OF 6	N/A
40	EVERY 4TH	2	1	1 OUT OF 4	N/A
45	EVERY 4TH	2	1	2 OUT OF 5	N/A
50	EVERY 4TH	2	1	2 OUT OF 4	N/A
50	EVERY 4TH	3	0	2 OUT OF 5	APPROX. 1 OUT OF 4
60	EVERY 4TH	3	0	3 OUT OF 5	APPROX. 1 OUT OF 4
40	EVERY 5TH	2	2	2 OUT OF 4	N/A
45	EVERY 5TH	3	1	2 OUT OF 4	APPROX. 1 OUT OF 4
45	EVERY 5TH	4	0	2 OUT OF 5	APPROX. 1 OUT OF 4
50	EVERY 5TH	4	0	2 OUT OF 4	APPROX. 1 OUT OF 4

A

Harvest Intensity

Harvest intensity may be regulated by controlling percentage of stems or BA removed. Random removals result in proportionately equal reduction in BA and stems per acre while selective removals based on diameter will remove a disproportionate percentage of BA. Controlling number of stems removed is quantitative while controlling BA requires more experience, as it is done intuitively. It is generally recommended to retain larger diameter trees, within a given species, assuming other tree characteristics are acceptable. Therefore, for most prescriptions it is recommended to base harvest intensity on percentage of stems removed, with the understanding a lesser percent of BA will be removed and average stem diameter will be increased.

B

Access Rows

Complete removal of individual rows is necessary to provide access for harvest equipment. Frequency of access row removal generally occurs every 3rd, 4th or 5th row and accounts for 33, 25 and 20 percent of stem removal, respectively. Fewer access rows allow for more individual tree selections to favor desirable traits, therefore, for most applications, using every 4th or 5th row for access is preferred.

C

Thinned Rows

Selective stem removal along rows, both adjacent to and once removed from access rows, can be used to manipulate parameters such as residual stem diameter, species composition, and desirable habitat components.

D

Untreated Rows

No removals along uncut rows result in horizontal variability of sunlight penetration as well as retention of habitat components (e.g., stressed, vine-laden or broken top trees). To meet objectives for WRE priority species, retaining these habitat components is recommended by either leaving periodic uncut rows, tree marking, harvest rules, or establishing no-cut zones throughout the treatment area.

E

Rate of Tree Removal on Adjacent Rows

Selections for tree removal, by timber marker or cutter operator, are feasible and efficient when evaluating 3 to 5 stems simultaneously. This also facilitates control of proportion of stems removed. When favoring trees based on diameter, average diameter of retained trees will inherently change based on rate of removal on thinned rows. When favoring large diameters, cutting 1 of every 4 stems may result in a relatively small average diameter for trees removed, subsequently reducing the size of canopy gaps. In comparison, cutting 3 of every 4 stems forces markers to select some larger trees for removal, resulting in greater BA and crown size per tree removed. Cutting 2 of every 4 stems seems to provide a desirable balance of achieving intended crown release while not taking a disproportionate amount of larger diameter/preferred trees. Favoring by diameter is most applicable in monospecific stands. In mixed species stands, caution should be used to prevent disproportionate removals of desirable species with smaller average diameters.

F

Rate of Tree Removal on Once Removed Rows

Thinning is most efficient on rows immediately adjacent to access rows and less efficient on rows once removed when conducting selective thinning in a mechanized operation. Therefore, fewer trees will generally be selected and removed from the once removed row.

TREE REMOVAL METHODS & PATTERNS

Careful thought should be given to prescribing an effective combination of tree removal treatments to meet management objectives. The following tree removal methods provide key considerations in formulating a harvest prescription. Table 5 represents alternative approaches to applying thinning treatments based on arrangement of trees and alternative tree removal methods described.

Thinning

Thinning can be described as removal of individual or small groups of trees (e.g. < 1/20-ac or < 15trees) to improve growth and vigor of residual trees by reducing competition from neighboring trees. Lightly thinned stands can result in relatively small canopy openings, and subsequently, crown closure may occur relatively quickly.

Row Thinning

Strict single row or multi-row thinning is not recommended, but rather a combination of periodic, complete row removal for equipment access (Table 5, Column 2), with selective tree removal from retention rows between completely removed rows (Table 5, Column 3). This provides opportunity for individual tree selection between removed rows to favor desired characteristics or habitat components (e.g., larger diameter, clean/straight boles, and unique or limited tree species within the stand).

Approximate percentage of stems to be cut (Table 4) can be regulated by defining the frequency of access rows (e.g., every 3rd, 4th, 5th row, etc.) and proportion of stems to be removed on retention rows (e.g., 1 of 4, 2 of 4, 3 of 5, etc.). Thinning corridors for equipment access can be similarly applied in stands without discernable rows while also minimizing damage to residual trees. Either can be administered by marking individual stems or by allowing operator selection. However, in absence of rows, operator experience is essential.

Two thinning approaches in Table 5 may be considered with regard to access row removal and retention row thinning. Row A of the table represents removing every 3rd, 4th or 5th row (Column 2) as access, with thinning all retention rows. This approach results in more uniformly distributed canopy gaps and thus producing more uniform light penetration following treatment. Since all rows are treated in this approach, select or unique habitat components (e.g., stressed, vine-laden or broken topped trees) may be retained by marking leave trees, establishing cutting rules, or identifying no cut zones. Row B of the table represents removing every 4th or 5th row as access and retaining some retention rows as untreated (Column 4). In this approach, select thinning is concentrated along access rows, with thinning conducted

TABLE 5: Alternative approaches to access and retention row thinning based on treatment method.

	HARVEST APPROACH	ACCESS ROW FREQUENCY	THINNED ROWS	UNTREATED ROWS
A	THINNING ALONG ALL RESIDUAL ROWS	EVERY 3RD	2	0
		EVERY 4TH	3	0
		EVERY 5TH	4	0
B	THINNING WITH RETENTION OF UNTREATED ROW(S)	EVERY 4TH	2	1
		EVERY 5TH	2	2
		EVERY 5TH	3	1
C	THINNING THROUGH RETENTION OF SMALL CLUSTERS OF TREES	5TH OR 6TH	N/A	N/A
D	GROUP REMOVAL	4TH, 5TH, OR 6TH	YES	MAY OR MAY NOT
			NO	ALL BUT ACCESS
E	PATCH CUT	N/A	N/A	N/A

primarily in immediately adjacent rows only. Leaving periodic untreated rows allows for automatic retention of some desirable habitat characteristics, as well as horizontal variability in light penetration.

Selected access row frequency should be a guide and not a rule that prevents operator discretion. Access row removal may also shift at times in mid-row if necessary to avoid harvest of infrequently occurring species or unique habitat components. Complete row removals are generally not recommended to be used alone as a thinning approach. They are generally best used in conjunction with selective thinning or providing access for group removals or patch cuts.

Cluster Retention Thinning

Application of this method is most efficient when focusing on identifying trees for retention rather than removal. Clusters are generally marked between access rows that occur every 5th or 6th row within a plantation (Table 5, Row C, Column 2). The residual stand will be comprised of clusters of trees established at irregular intervals with variable-sized canopy gaps between them. Retention clusters should be comprised of 5 to 10 trees to ensure most stems in the cluster receive some crown relief. Intensity or percent of tree removal across the stand is regulated by number of clusters per acre and average tree count per cluster. Cluster location can be identified either by marking all stems to be retained or one individual in the center of the cluster—the latter is most efficient but provides less opportunity for individual tree selections to foster desired tree characteristics. Clusters may be established in a manner which insures they encompass trees of preferred species, stem quality or with desirable habitat components, as well as to create varying-sized canopy openings. Cluster thinning can result in larger and more variable-sized canopy gaps than row thinning of equal intensity, but still provides some crown release for nearly all individuals retained. It may provide less control over individual tree selections than thinning along rows. However, it offers flexibility in arrangement of residual stems leading to greater variability in size and spatial distribution of canopy gaps. This approach can be applied with or without discernable rows.

Group Removal

Removal of trees in groups (e.g. 1/10 to 1/4 acre or 30 to 75 trees) is intended to create canopy gaps sufficient in size to preclude bordering crowns from re-occupying the gap long enough to allow development of shade intolerant plants that may not be prevalent under a uniformly thinned canopy. These gaps are created specifically to lengthen persistence of understory vegetation and improve species diversity post-thinning. They may be incorporated as part of a more uniform pre-described row thinning operation or as a stand-alone treatment. Group removals reduce stand-level stocking, but when used alone, do not result in a similar proportion of "released" crowns as would an equivalent stocking reduction applied in a row thinning treatment. Percent of stand removal using the group method may be better guided by area regulation (e.g. number of groups or frequency of some average size across the stand). As a rule, group removals should generally comprise no more than 5 to 10 percent of total stand removal when applied in conjunction with row thinning. If used alone, groups must be connected and sufficient in area/number to facilitate commercial harvest. Therefore, a higher rate of removal (20 to 30 percent) would be warranted.

Patch Cuts

These are openings at least as wide as three times the average height of co-dominant trees. They are complete, or nearly complete, overstory removals in openings ½- to four acres in size (approximately 150 to 1200 trees), and thus provide little crown relief/benefit to trees beyond those bordering the opening. Patches may be established to create substantial areas of early successional habitat or to create a two-aged stand. Patch cut openings should not exceed 20 percent of the area **unless the treatment is specifically intended to regenerate a stand deemed unsuccessful** (e.g. stands with high proportion of off-site species performing poorly or exhibiting very low stem count).

APPENDIX 1

Participants in the Tri-state Conservation Partnership's, Wetland Reserve Easements Forest Management Working Group

BUDDY DUPUY (Co-chair)
Wildlife Forester
Louisiana Department of Wildlife and Fisheries

STEVE BROCK (Co-chair)
Partnership Coordinator
Lower Mississippi Valley Joint Venture

RON SEISS (Co-chair)
Lower MS River Program Director
The Nature Conservancy

DOUG AKIN
Assistant State Forester
Arkansas Forestry Commission

JAMES AUSTIN
Partners Biologist
U.S. Fish and Wildlife Service Mississippi Partners for Fish & Wildlife

BRIAN BALLINGER
Director
Mississippi River Trust

DAVID BREITHAUPT
Farm Bill Coordinator
Louisiana Department of Wildlife and Fisheries

NICK BIASINI
Regional Biologist
Ducks Unlimited, Southern Regional Office

MIKE BLAZIER
Forestry Research Project Leader
Louisiana State University

JAMES CALLICUTT
Regional Biologist
Ducks Unlimited, Southern Regional Office

ALEC CONRAD
Private Lands Biologist
Mississippi Department of Wildlife, Fisheries and Parks

GERALD DAVIS
Assistant Forester
U.S. Fish and Wildlife Service, Tensas River National Wildlife Refuge

ANDY DOLAN
State Coordinator
U.S. Fish and Wildlife Service, Louisiana Partners for Fish & Wildlife

DUSTIN FARMER
Easement Program Specialist
Natural Resources Conservation Service, Louisiana

BRENT FREY
Assistant Professor of Forestry
Mississippi State University

BUBBA GROVES
Private Lands Biologist
Arkansas Game and Fish Commission

JOHN GRUCHY
Private Lands Program Coordinator
Mississippi Department of Wildlife, Fisheries and Parks

ALAN HOLDITCH
State Forester
Natural Resources Conservation Service, Mississippi

HOUSTON HAVENS
Waterfowl Program Coordinator
Mississippi Department of Wildlife, Fisheries and Parks

CINDY NEAL
Easements Coordinator
Natural Resources Conservation Service, Arkansas

KEVIN NELMS
Wildlife Biologist
Natural Resources Conservation Service, Mississippi

MICHAEL RENFROW
Private Lands Biologist
U.S. Fish and Wildlife Service, Louisiana Partners for Fish & Wildlife

NATHAN RENICK
Forester
U.S. Fish and Wildlife Service, Tensas River National Wildlife Refuge

GEORGE RHEINHARDT
Forester
Natural Resources Conservation Service, Arkansas

WAYNE ROBERTS
Forester
Natural Resources Conservation Service, Louisiana

DAN SCHEIMAN
Bird Conservation Director
National Audubon Society, Arkansas Chapter

RICK WILLIAMS
State Forester
Natural Resources Conservation Service, Louisiana

NANCY YOUNG
State Resource Conservationist
Natural Resources Conservation Service, Arkansas

APPENDIX 2

Non-commercial Treatment Alternatives

Due to the associated costs to conduct pre-commercial or non-commercial thinning treatments, it is often not a preferred or viable management alternative. However, in some instances it may be the only alternative to passive management. Particularly in areas with weak or non-existent markets for low-value wood products. Such may be the case for some regions with significant acreage enrolled in WRE. It is also likely some landowners will have personal wildlife management objectives that concurrently meet NRCS WRE habitat goals (i.e. migratory neo-tropical songbirds, wetland dependent wildlife, & threatened and endangered species) but may only be achieved through pre-commercial thinning. Thus, non-commercial removal should be an option for landowners willing to conduct these treatments to meet habitat management objectives. There are numerous approaches to pre-commercial thinning. Research identifying the most effective methods for applying pre-commercial treatments to achieve desired habitat conditions is limited. The following alternatives present estimated costs based on 2014 data and include both pros and cons for consideration of non-commercial stand treatment methods.

Recently Thinned Plantation

MULCHING

COST

Estimated cost is $150-180/hr., most contractors require an 8 hr minimum ($1200 -$1440 minimum); as a rule of thumb, 6" and under material requires 8 hr/1 ac; cost per acreage varies greatly depending on density and size of trees and equipment type.

PROS

- Disturbance of the litter layer and soil scarification generally improves understory vegetative response as compared to non-mechanized treatments

CONS

- Application across large areas can sometimes be cost-prohibitive

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CHEMICAL

(Injection, hack-and-squirt, basal spray, cut-stump)

COST

Estimated cost is $65-120, differences in costs will generally be related to the density and size of stems to be removed; variations in costs are influenced by the type and volume of chemicals applied.

PROS

- Affords the best selectivity in application and less cost compared to mechanized treatments
- Provides most effective approach to control non-native species/invasive species
- Experienced contract crews can treat large acreages quickly, but may also be applied by landowners/leaseholders given a well-developed treatment prescription
- Would result in increased snags and course woody debris, beneficial to desired habitat conditions, as compared to mechanized treatment

CONS

- Risk of impact to non-target species if improperly applied
- Potential or perceived negative environmental impacts

MECHANIZED HARVESTING EQUIPMENT

COST

Estimated cost is unknown. Utilizing mechanized logging equipment for non-commercial removal as a general rule, is only viable when accomplished in combination with a commercial harvest operation

PROS

- Likely one of the best ways to treat large acreages in a short amount of time
- Increases presence of course woody debris
- Understory response expected to be greater than from non-mechanized treatments
- Felled trees can improve cover for a variety of wildlife species

CONS

- Will likely require additional alternative thinning treatment as this approach may not allow adequate selectivity
- Likely infeasible in most situations due to difficulty in identifying a logger willing to conduct a noncommercial harvest operation

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CHAINSAW

COST

Estimated cost is unknown. Generally not used as stand-alone treatment; uncommon due to contractor liability costs

PROS

- Complete felling greatly increases amount of course woody debris, but is short-lived compared to injection
- Felled tree canopies remain relatively intact and promote substrate for vines, also creates excellent cover for species that use brush piles
- Could be applied by a landowner/leaseholder on small acreages
- Snags could be created by double girdling trees

CONS

- Should not be used if coppice regeneration is not desired
- Intact litter layer may help prevent significant understory vegetation development

APPENDIX 3

Decision Matrix

	INDICATOR/INVENTORY DATA	NEXT STEP RECOMMENDATIONS AND TREATMENT DECISIONS
UNDERSTORY INDEX	< 220	Inventorying stand to determine stocking levels is advisable; crown thinning is likely warranted
UNDERSTORY INDEX	> 220 & < 320	Conduct stand inventory to determine stocking levels; thinning stand may benefit mgmt objectives, but is optional; refer to stocking guide (Figure 2)
UNDERSTORY INDEX	> 320	Delay thinning
LCR	< 30% Ash, Cottonwood < 40% Most other species < 50% Willow Oak, Cypress, Overcup Oak	Inventorying stand to determine stocking levels is generally advisable; crown thinning is likely warranted
LCR	30-60% Ash, Cottonwood 40-70% Most other species 50-80% Willow Oak, Cypress, Overcup Oak	Conduct stand inventory to determine stocking levels; thinning stand may benefit mgmt objectives, but is optional; refer to stocking guide (Figure 2)
LCR	> 60% Ash, Cottonwood > 70% Most other species > 80% Willow Oak, Cypress, Overcup Oak	Delay thinning
STOCKING	> 80%	Stand treatment is generally warranted; develop treatment plan to include general crown thinning[2]
STOCKING	70-80%	Thinning stand may benefit mgmt objective, but optional
STOCKING	60-70%	Review stand and landscape level conditions; reduce thinning intensity of necessary to maintain residual stocking above C-10 line[3]
STOCKING	< 60%	Delay thinning

1 To strengthen inventories, stands should be stratified based on similarities in species composition, stem diameter and stem densities. Data will be used to develop prescriptions and should be analyzed from delineable, contiguous areas which will become treatment units.

2 General crown thinning is warranted, group removals and patch cuts may or may not be prescribed based on management objectives as well as stand and landscape level conditions.

3 Refer to Table 3 - Thinning intensity alternatives and their relationship to the recommended B-line and C10-line residual stocking (Figure 1) based on initial stocking level and quadratic mean diameter.

4 Extenuating circumstances may include: large expanses lacking early successional habitat, monotypic overstories with mixed species, advanced regeneration, preponderance of off-site species, and excessive proportion of poor-quality stems.

ASSUMPTIONS	COMMENTS
Understory suppressed by low light levels and not water inundation[1]	Stocking is likely relatively high; stand will likely benefit from thinning
see footnote[1]	Thinning may benefit habitat conditions but is probably not necessary to maintain tree health/growth
Incomplete crown closier is resulting in sufficient sunlight to maintain a robust understory[1]	Stocking is probably too low to warrant treatment
LCR thresholds apply to relatively pure stands; for stands with more diverse tree species composition, conduct inventory to determine stocking levels[1]	Low LCR probably indicative of high tree stocking; stand will likely benefit from thinning
LCR thresholds apply to relatively pure stands; for stands with more diverse tree species composition, conduct inventory to determine stocking levels[1]	Degree of stocking is not easily estimated from LCR
LCR thresholds apply to relatively pure stands; for stands with more diverse tree species composition, conduct inventory to determine stocking levels[1]	Stocking is probably low; continued stand growth and crown closure necessary to facilitate desirable self pruning
Stocking is relatively uniform and not "inflated" by occasional oversized trees in stand inventory (diameter distribution curve bell-shaped)[1]	Stocking is relatively high; diameter growth of trees will likely be enhanced from thinning
see footnote[1]	Stand-level habitat may be enhanced by treatment, but tree health and vigor probably not in jeopardy
see footnote[1]	Thinning generally not recommended; however, extenuating stand level or landscape level conditions may warrant some form of treatment[4, 5]
see footnote[1]	Thinning is not recommended; however, extenuating stand level or landscape level conditions may warrant some form of treatment[4, 5]

5 When treatment is determined to be warranted, group removals and/or patch cuts may be used in place of crown thinning. For example, if habitat lacks structure and early successional vegetation but general crown thinning is not prescribed because further bole-pruning is desired, up to 20-30% of stand may be treated with one or both types of tree removal patterns. Groups are 1/10 to1/4-ac in size and may comprise up to 20-30% of treated area if used alone. Patch cuts are 1/2 to 4 acres and should not exceed 20% of treated area. In combination, these complete overstory removals should not exceed 30% of stand UNLESS being used specifically to regenerate a stand deemed unsuccessful.

* Decision Matrix is based on current understanding of accepted forest management techniques along with field-based application and experience as of March 2016. Future field application and research may lead to amendment of recommendations.

APPENDIX 4

Understory Index, Live Crown Ratio & Invasive Species Tally Sheet

Tract I.D.: ______________________________ Stand/Unit: _______________________ Date: ______________________

Plot Size (if applicable): ________________ Crew: ____

UNDERSTORY		point									
index	**pt. value**								**% of points**	**computation**	**score**
very low	1										
low	2										
medium	3										
high	4										
very high	5										
TOTAL									100%		

LIVE CROWN RATIO	plot/point							**Avg % LCR**
estimate from several individual codominants at each point								

INVASIVE SPECIES	Note ALL observed around each point. Do NOT restrict sampling to fixed-area plots						
tallow 1-6' in height							
tallow > 6'							

Species of particular concern include tallow, privet, and tri-foliate orange, but note any non-native species. Estimate numbers per acres: NONE, 5, 10, 25, 60, 100, 200, 300, etc.....

***REGENERATION**	plot/point #						
tree seedlings 1-6' in height							
overtopped sapplings > 6'							
list most prevelant species							

*NOTE: it is NOT necessary to tally regeneration in well-stocked, diverse conditions where regenerating the stand is unnecessary. But, regeneration should be evaluated in mono-specific stands where the treatment prescription may call for releasing other species to increase diversity.
Number of seedlings per acre may be quantified from fixed-area plots or estimated from the general area around each plot.
Estimate number per acre as: none, 10, 25, 50, 100, 150, 200, 300 etc....
Tree species should be noted but need not be tallied individually; list most prevalent
TREE SPECIES
ABBREVIATIONS : ____

APPENDIX 5A

Fixed-area Inventory - Overstory Tally Sheet

Tract I.D.: ______________________________ Stand/Unit: ______________________ Date: _____________________

Plot Size (overstory): ___________________ Crew: ____

plot:			4.51-5.5		6.51-7.5							
SPECIES	**2"**	**3"**	**4"**	**5"**	**6"**	**7"**	**8"**	**9"**	**10"**	**11"**		

*REGENERATION		
Plot Size: (if applicable)	seedlings 1’-6’	overtopped saplings >6’
estimated in and around plot		
quantified within fixed-area plot		
SPECIES		

plot:			4.51-5.5		6.51-7.5							
SPECIES	**2"**	**3"**	**4"**	**5"**	**6"**	**7"**	**8"**	**9"**	**10"**	**11"**		

*REGENERATION		
Plot Size: (if applicable)	seedlings 1’-6’	overtopped saplings >6’
estimated in and around plot		
quantified within fixed-area plot		
SPECIES		

plot:			4.51-5.5		6.51-7.5							
SPECIES	**2"**	**3"**	**4"**	**5"**	**6"**	**7"**	**8"**	**9"**	**10"**	**11"**		

*REGENERATION		
Plot Size: (if applicable)	seedlings 1’-6’	overtopped saplings >6’
estimated in and around plot		
quantified within fixed-area plot		
SPECIES		

plot:			4.51-5.5		6.51-7.5							
SPECIES	**2"**	**3"**	**4"**	**5"**	**6"**	**7"**	**8"**	**9"**	**10"**	**11"**		

*REGENERATION		
Plot Size: (if applicable)	seedlings 1’-6’	overtopped saplings >6’
estimated in and around plot		
quantified within fixed-area plot		
SPECIES		

*NOTE: it is NOT necessary to tally regeneration in well-stocked, diverse conditions where regenerating the stand is unnecessary. But, regeneration should be evaluated in mono-specific stands where the treatment prescription may call for releasing other species to increase diversity.

Number of seedlings per acre may be quantified from fixed-area plots or estimated from the general area around each plot.

Estimate number per acre as: none, 10, 25, 50, 100, 150, 200, 300 etc....

Tree species should be noted but need not be tallied individually; list most prevalent

TREE SPECIES

ABBREVIATIONS : ____

APPENDIX 5B

Sample Fixed-area Inventory - Overstory Tally Sheet

Tract I.D.: ______________________________ Stand/Unit: ______________________ Date: ____________________

Plot Size (overstory): 1/50-ac ___________Crew: ____

plot :1				4.51-5.5		6.51-7.5						
SPECIES	**2”**	**3”**	**4”**	**5”**	**6”**	**7”**	**8”**	**9”**	**10”**	**11”**		
Nuttall						• • •	•					
ash					•							
sugarberry			•									
Am. elm				•								

*REGENERATION		
Plot Size: (if applicable)	seedlings 1’-6’	overtopped saplings >6’
estimated in and around plot		
quantified within fixed-area plot		
SPECIES		

plot: 2				4.51-5.5		6.51-7.5						
SPECIES	**2”**	**3”**	**4”**	**5”**	**6”**	**7”**	**8”**	**9”**	**10”**	**11”**		
Nuttall						•	• •	•				
ash			•									
Am. elm		•										

*REGENERATION		
Plot Size: (if applicable)	seedlings 1’-6’	overtopped saplings >6’
estimated in and around plot		
quantified within fixed-area plot		
SPECIES		

plot: 3				4.51-5.5		6.51-7.5						
SPECIES	**2”**	**3”**	**4”**	**5”**	**6”**	**7”**	**8”**	**9”**	**10”**	**11”**		
Nuttall					• •	•		•				
sugarberry		• •	•									

*REGENERATION		
Plot Size: (if applicable)	seedlings 1’-6’	overtopped saplings >6’
estimated in and around plot		
quantified within fixed-area plot		
SPECIES		

OVERSTORY

Ascertaining stand level stocking from stocking guide (Figure 1), requires use of at least two of the following variables, trees per acre (TPA), quadratic mean diameter (QMD), or stand basal area per acre (BA). [NOTE: For the purpose of this document, substituting arithmetic mean diameter (DBH) in place of QMD will provide sufficient accuracy to develop harvest prescriptions. In sample below, DBH is 6.2” and QMD is 6.4”; stand density is 333 TPA which corresponds to stocking levels of 73% and 77% respectively, based on stocking guide.]

QMD is calculated by first dividing BA/ac by TPA to determine average BA/tree (74.8/333 = 0.22462 ft2/tree) then determining the diameter that corresponds to that average BA using the formula: BA = 0.005454 D2.; in this example, 0.22462 = 0.005454 D2. Next, divide both sides of the equation by 0.005454 and take the square root of the quotient. 0.22462/0.005454 = 41.18. The sq root of 41.18 = 6.4” = QMD for this data set.

Trees Per Acre: 20 trees/3 plots = 6.66/plot x 1/50th ac = **333 tpa**

Arithmetic Mean Diameter (average DBH): 123"/20 trees = **6.2"**

Basal Area: 4.4886/3 plots = 1.4962 x 1/50-ac = **74.8 ft^2**

Quadratic Mean Diameter: 74.8/333 trees = 0.22462 ft^2/tree = **6.4"**

SUMMARY												
DBH	2"	3"	4"	5"	6"	7"	8"	9"	10"	11"		
number of trees by diameter		2	3	2	3	5	3	2				
total inches		6	12	10	18	35	24	18			sum	123"

BASAL AREA = (0.005454) (diameter sq.)

(0.005454) (3^2) = 0.04909 x 2 trees = 0.0981 ft^2

(0.005454) (4^2) = 0.08726 x 3 trees = 0.2618 ft^2

(0.005454) (5^2) = 0.13635 x 2 trees = 0.2727 ft^2

(0.005454) (6^2) = 0.19634 x 3 trees = 0.5890 ft^2

(0.005454) (7^2) = 0.26725 x 5 trees = 1.3362 ft^2

(0.005454) (8^2) = 0.34906 x 3 trees = 1.0472 ft^2

(0.005454) (9^2) = 0.44177 x 2 trees = 0.8835 ft^2

20 trees = 4.4886 ft^2

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Lower Mississippi Valley
JOINT VENTURE

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