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Implementing Northern Goshawk Habitat Management in Southwestern Forests: A Template for Restoring Fire-Adapted Forest Ecosystems

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ABSTRACT

Developing and displaying forest structural targets are crucial for sustaining the habitats of the northern goshawk, a sensitive species in Southwestern forests. These structural targets were described in Management Recommendations for the Northern Goshawk in the Southwestern United States (MRNG) (Reynolds, et al., 1992). The MRNG were developed in a unique food-web approach that identified desired forest conditions for the goshawk. These desired conditions were based on syntheses of the habitats of both goshawks and the diverse suite of plants and animals in their food web. Not surprisingly, implementing these structural targets results in forests restored to conditions similar to our understanding of pre-European settlement forests.

Silviculturists are responsible for:

1) developing a silvicultural system,
2) documenting the system in a silvicultural prescription, and
3) establishing protocols for monitoring the development and perpetuation of the desired forest conditions.

We present spreadsheet tools to aid silviculturists with diagnosis and development of silvicultural prescriptions and tree-marking guides that produce the desired uneven-aged, heterogeneous forest structures that comprised historic forests, as well as goshawk habitats, in Southwestern ponderosa pine landscapes. These tools incorporated fire behavior and fuel considerations, rendering them appropriate for developing prescriptions for other management objectives (e.g., restoration of fire-adapted forest ecosystems) and biophysical situations.

Key words: forest management, marking guides, northern goshawk, reference conditions, restoration, silvicultural prescriptions, structural targets

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HISTORY OF GOSHAWK HABITAT MANAGEMENT IN THE SOUTHWEST

The northern goshawk (*Accipiter gentilis*) is a large forest raptor that typically occurs in old forests and feeds on birds and mammals such as tree and ground squirrels, rabbits, jays, woodpeckers, and grouse. Many of these prey species are more abundant in older forests (Squires and Reynolds, 1997). Over the last 30 years, considerable controversy has developed regarding the conservation of the goshawk (Greenwald, et al., 2005). It has been suggested that tree harvests negatively affect goshawks by altering the composition and structure of their habitats (Reynolds, 1971; Reynolds, et al., 1982; Moore and Henny, 1983), and Crocker-Bedford (1990) showed that territory occupancy and reproduction of goshawks in northern Arizona were lowered by tree harvests. These findings initiated a flurry of appeals and litigation aimed at reducing tree harvests in the Southwest and provided the basis for petitions to list the goshawk as threatened (Boyce, et al., 2006). In response to these challenges, the Southwestern Region of the Forest Service (FS) convened a scientific committee of goshawk biologists and silviculturists to develop forest management recommendations to protect and enhance habitats of the goshawk in the southwestern United States (Boyce, et al., 2006). The committee's recommendations were published in the Management Recommendations for the Northern Goshawk in the Southwestern United States (hereafter MRNG) (Reynolds, et al., 1992). In 1996, management standards and guides (hereafter "guidelines") were developed by the Southwestern Region based on the MRNG, which appeared in a Final Environmental Statement for amending National Forest Management Plans in Arizona and New Mexico (Boyce, et al., 2006). In 1996, a Record of Decision (ROD) amended the Forest Management Plans to implement the MRNG in all National Forests in the Southwest (USDA Forest Service 1996). The Plan Amendment directed National Forests to apply the goshawk guidelines in almost all vegetation manipulation projects (timber sales and fuels management treatments). An initial strategy was developed in 1993 (Higgins, 2003) for implementing the guidelines on the Kaibab National Forest (KNF), based on the concepts and desired forest conditions described in the MRNG. Despite this, there continued to be uncertainty in forest management applied in the Southwest regarding the MRNG desired forest conditions (Boyce, et al., 2006). Here we present tools to help managers with the process of prescription development, implementation layout, and monitoring. These tools facilitate understanding and application of the concepts outlined in the MRNG and meeting the guideline specifications outlined in the ROD.

GOSHAWK HABITAT MANAGEMENT: FOREST ECOLOGY

The MRNG described sets of desired goshawk breeding habitats for Southwestern forests based on syntheses of the life history and habitats of goshawks and 14 important Southwestern goshawk prey species and the ecology of dominant overstory and understory plants in each forest type (Reynolds, et al., 1992; Reynolds, et al., 2006). The MRNG described habitats at three spatial scales:

(1) a 12-ha (30-acre) nest area with relatively large trees and high canopy cover relative to forest type,

(2) a 168-ha (420-acre) post-fledging family area (PFA) surrounding the nest area providing a transition from forest structures similar to those in nest areas to structures suitable for goshawk foraging (see below), and

(3) a 2,160-ha (5,400-acre) foraging area surrounding the PFA comprised of structures suited for goshawk foraging and mosaics of prey habitats (Reynolds, et al., 1992) (Figures 1-2).

Goshawk foraging habitat included subcanopy flight space (lifted crowns), abundant tree perches, and available prey. Prey habitats included highly interspersed groups of mid-aged (140+ years) and old trees (230+ years) with interlocking tree crowns (for tree squirrels), small openings (typically <0.5 ha, 1.25 acre) around tree groups (for ground squirrels, rabbits, birds), decadent reserve trees and snags (for woodpeckers, tree squirrels), logs (for ground squirrels, rabbits, woodpeckers), and wood debris (for ground squirrels, rabbits, birds) (Reynolds, et al., 1992). Mid-aged, mature, and old forests provided the best habitat for most prey species, but small openings were also important (Reynolds, et al., 1992). Old forests also provide subcanopy flight space suited for goshawk hunting. Predator and prey habitats were synthesized into desired landscapes so that the distribution and interspersion of habitats optimized their availability to territorial goshawks and their prey with an objective of maximizing goshawk occupancy, reproduction, and survival (Reynolds, et al., 2006b). To

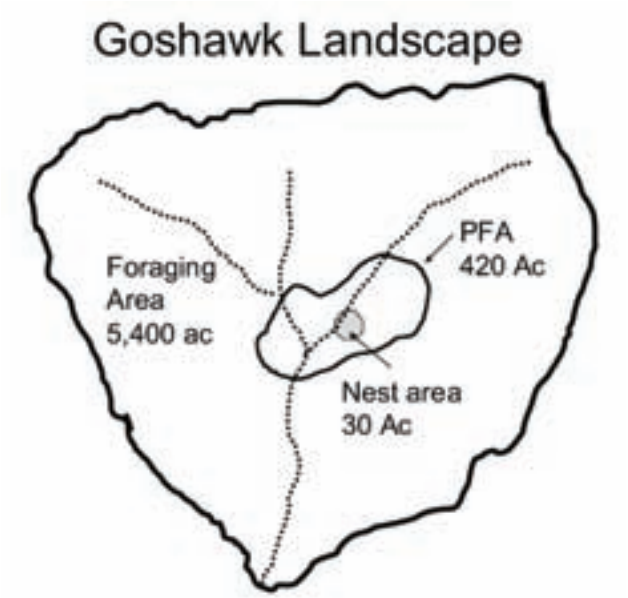


Figure 1. Conceptualized Goshawk Home Range

assure that the specific desired habitats were within the biophysical capabilities of a forest and could therefore be attained and sustained, the MRNG developed specific desired conditions for Southwestern ponderosa pine, mixed conifer, and spruce/fir forests by incorporating local and regional variations in vegetation composition and structure, tree development rates and longevity, natural disturbances and succession, the sizes, shapes, juxtapositions of plant aggregations, and site capabilities (Reynolds, et al., 1992, Reynolds, et al., 1996, Long and Smith 2000, Reynolds, et al., 2006).

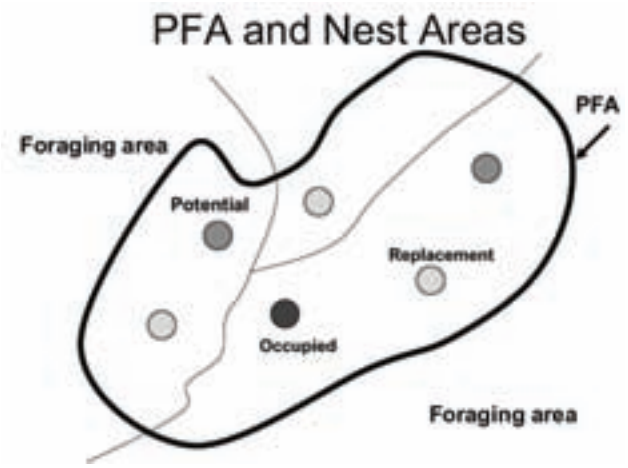


Figure 2. Conceptualized Goshawk PFA and Nest Areas

The intent of the MRNG was to maintain goshawk reproduction by sustaining predator and prey habitats on each home range and used vegetative structural stages (VSS) to describe the desired vegetation. VSS integrates the stages that vegetation complexes (e.g., composition, structure) go through beginning with regeneration through maturation and mortality (Oliver and Larsen 1990, Franklin, et al., 2002, Thomas et al. 1979). The MRNG defines 6 vegetation structural stages from forest initiation (VSS 1) to old forest (VSS 6) (Figure 3). Due to forest dynamics (e.g., resulting from vegetation growth, succession, natural disturbances) landscapes entirely of old forest (VSS 6) can not be sustained. Therefore the MRNG used maturation rates of Southwestern forests to estimate sustainable landscape proportions of old forest, and recommended that about 10% of a naturally forested landscape be in a grass/forb/shrub stage (VSS 1; to 20 yrs), 10% in the seedling/sapling stage (VSS 2, to 50 yrs), 20% in young forest (VSS 3; to 96 yrs), 20% in mid-aged forest (VSS 4; to 137 yrs), 20% in mature forest (VSS 5; to 183 yrs), and 20% in old forest (VSS 6; to 233+ yrs) (Reynolds, et al., 1992, Appendix 5, Table 1). Excluding grass/forb/shrub, each VSS comprised similarly-aged trees and elements such as live-tree decadence, snags, logs, and vertical and horizontal heterogeneity. Over time (≈ 250 years), the desired landscape consisted of a temporally shifting mosaic of highly interspersed VSS groups in the desired proportions of VSS (Reynolds, et al., 1992, Long and Smith 2000). Sizes of VSS groups approximated the natural (prior to tree harvests and fire suppression) conditions in these forests and contained 2 - 44 trees occupying 0.2-0.3 ha (0.5- 0.75 acre) (Cooper 1961, White 1985, Pearson 1950). At the coarse scale (landscape), ponderosa pine was all-aged, but trees within each group (fine scale) tended to be similar age (Pearson 1950). The desired within-group structure in the mid-aged to old classes (VSS 4-6) included open understories, interlocking tree crowns, abundant large limbs (goshawk hunting perches), and shade for mycorrhizal fungi (food of several prey species) (Reynolds, et al., 1992). Grass, herb, shrub habitat was interspersed in and around groups and provided habitat for rabbits, ground squirrels, and birds (e. g., grouse, doves) (Reynolds, et al., 1992). Additional desired conditions include retention of large live reserve trees within regeneration groups > 0.4 ha (1 acre) in size, snags, downed logs, and woody debris. An ideal MRNG landscape had home ranges spaced at about 4 km (2.5 mile) between centers (Reynolds, et al., 1992, Boal et al. 2001, Reynolds, et al., 2005, Reynolds and Joy 2006). Because

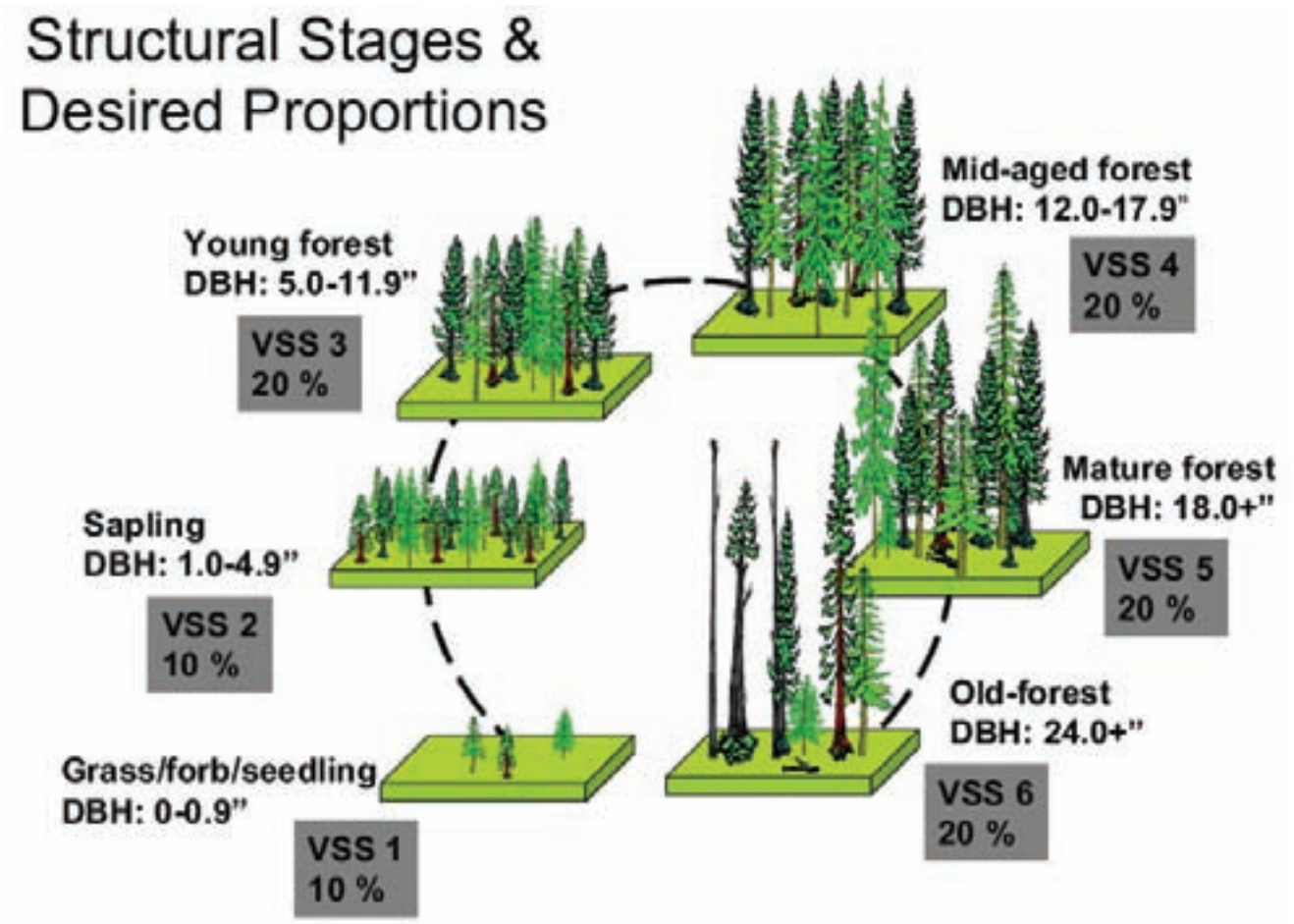


Figure 3. Forest Structural Stages

the desired MRNG condition for Southwestern ponderosa pine forests closely resembles the pre-European settlement (before grazing, fire control and major harvesting) conditions in this forest type (Cooper 1961, White 1985, Pearson 1950, Covington and Moore 1994, Fulé et al. 1997, Long and Smith 2000), implementation of the MRNG is a large step towards ecological restoration.

HISTORIC REFERENCE CONDITIONS: FOREST RESTORATION AND MRNG

Historic reference conditions (HRC) provides a framework for understanding forest conditions, ecological processes, and the historic range of variability prior to extensive European settlement (Moore and others 1999). Figure 4 shows historic forest patterns in the Fort Valley Experimental Forest near Flagstaff, Arizona (Covington, 1997). Note the similarity of historic forest tree group patterns to the desired conditions described under the MRNG. Such patterns are relevant for developing management strategies in Southwestern ponderosa pine and dry mixed-conifer forest types.

Following are some concepts related to MRNG and ecological restoration of historic reference conditions:

- Implementation of MRNG and other ecological restoration approaches based upon historic conditions will lead to restoration of forest resiliency to disturbances within the historic range of natural variability.
- Strict-sense ecological restoration involves restoration of historic reference conditions relative to forest structure, patterns, species and ecological processes. It is the end-goal of a process that provides for maintenance of desired conditions by re-introduction of or mimicking historic ecosystem processes (fire, insects,

etc.). It will hereafter be referred to as restoring historic reference conditions (RHRC). Some groups and individuals believe most, if not all, management actions on southwestern forests should be designed to restore HRC.

- MRNG is a strategy that provides for development, maintenance and sustainability of the desired forest structural conditions. These desired conditions are based on the habitat requirements of the goshawk and their prey species and are similar to the historic range of variability of natural forest conditions. Implementation of MRNG will result in forest landscape restoration (structure, patterns and species composition within this historic range of variability of natural forest conditions). But MRNG is a management system designed to provide sustainability within a management framework that recognizes multiple resource objectives. Resultant desired future condition of the MRNG strategy will be similar but not necessarily identical to RHRC, and the maintenance strategy may differ between the MRNG and RHRC.

The following are some implementation similarities and differences between MRNG and RHRC:

- Both approaches may utilize tree harvest as a tool for obtaining desired conditions. But some strict-sense RHRC advocates have suggested that desired conditions should be maintained by either prescribed fire or wildland fire use alone and tree cutting is not warranted. In contrast, MRNG utilizes tree cutting as a scheduled activity for maintaining desired forest conditions. Timber production isn't an objective, but rather is a by-product of maintaining structural composition. In addition, prescribed fire is the preferred method of treating surface fuels but mechanical and hand methods are not excluded. Because of this flexibility, implementing the MRNG appears to be more feasible than maintaining desired forest structures by prescribed fire alone.
- Grouped and single trees are interspaced within a grass/forb/shrub mosaic (see below) under both management approaches. This results in an irregular and discontinuous forest canopy with variable tree densities and discontinuous arrangement of fuels which minimizes the potential for crown fire and facilitates the use of low intensity prescribed fire. Therefore both MRNG and RHRC are applicable for decreasing fuels and crown fire hazard.
- Both RHRC and MRNG focus on development of clumps/groups of trees, surrounding root development zones, natural openings, and replacement trees arranged in fine scale mosaics [e.g., 0.04 to 0.8 ha (0.1 to 2.0 acre) in ponderosa pine forests].
- Depending on the setting, type and current forest condition, implementing the MRNG could tend to create and maintain even-aged groups of trees while the RHRC would tend to create uneven-aged groups. Nevertheless, depending on the frequency and intensity of treatments utilized by both approaches, a variety of forest compositions and structures could be maintained.
- The RHRC approach focuses on historic locations of tree groups and clumps based upon remnant evidence (stumps and logs representing pre-settlement trees) for determination of the number and location of replacement trees. Such pre-settlement evidence can also be used to develop desired forest structures identified in the MRNG. A key to using both historic reference conditions and the MRNG for treating forests is to use this information along with intrinsic site information such

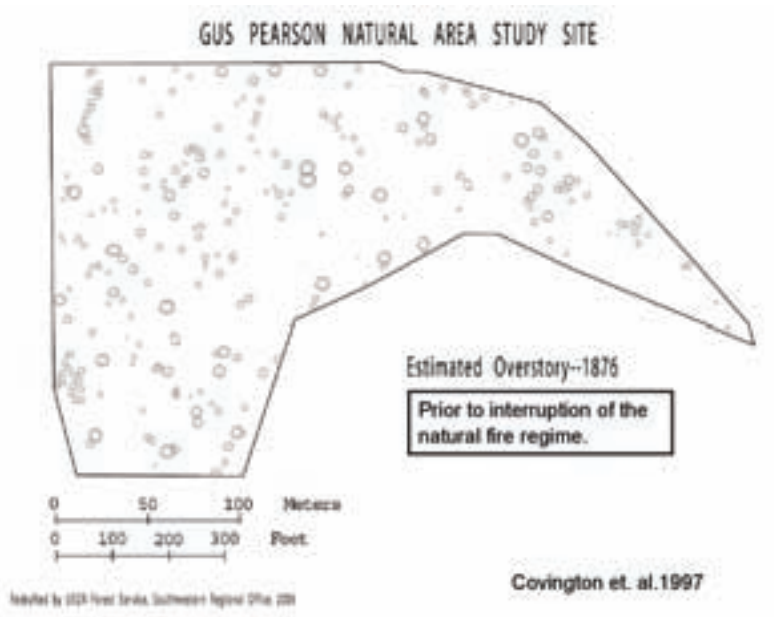


Figure 4. Historic Reference Conditions

Table 1. Forest Density and Structural Targets (Full Stocking Level, Ponderosa Pine PFA)

DESIRED FUTURE CONDITION

Ponderosa Pine Forest Type - All Sites - Post-Fledging Family Area

VSS Class	DBH Class	% of Area	Mean DBH	Group basis SDI	Group basis Mean Trees/ acre	Group basis Basal Area (ft^2/acre)	Group basis Canopy Cover (percent)	Per acre basis mean (average acre) Trees/ acre	Per acre basis mean (average acre) Basal Area (ft^2/acre)
1	<1	10	0.1	0	203	0		20.3	0
2	1-4.9	10	3	28	193	9		19.3	1
3	5-11.9	20	8.5	105	136	54		27.3	11
4	12-17.9	7	15	137	72	88	60	4.8	6
4	12-17.9	13	15	130	68	83	50	9.0	11
5	18-23.9	20	21	127	39	93	50	7.7	19
6	24+	20	27	135	27	109	50	5.5	22
								93.9	69
								Dq* =	13.11
								SDI* =	113.7

====== Note on per acre basis =======

Reserve trees and grass matrix areas are included in these figures. Trees are closely grouped, allowing for open rooting zone interspaces between groups.

*Quadratic mean diameter includes trees >= 1" dbh only.

Modeling assumptions: Site Index = 78 (Minor), Stand Density Index (SDI) max = 450

Table 2. Forest Density and Structural Targets (Full Stocking Level, Ponderosa Pine FA)

DESIRED FUTURE CONDITION

Ponderosa Pine Forest Type - All Sites - Foraging Area

VSS Class	DBH Class	% of Area	Mean DBH	Group basis SDI	Group basis Mean Trees/ acre	Group basis Basal Area (ft^2/acre)	Group basis Canopy Cover (percent)	Per acre basis mean (average acre) Trees/ acre	Per acre basis mean (average acre) Basal Area (ft^2/acre)
1	<1	10	0.1	0	203	0		20.3	0
2	1-4.9	10	3	28	193	9		19.3	1
3	5-11.9	20	8.5	105	136	54		27.3	11
4	12-17.9	20	15	89	46	57	40	9.3	11
5	18-23.9	20	21	100	30	73	40	6.1	15
6	24+	20	27	104	21	84	40	4.2	17
								86.5	54
								Dq* =	12.29
								SDI* =	92.1

====== Note on per acre basis =======

Reserve trees and grass matrix areas are included in these figures. Trees are closely grouped, allowing for open rooting zone interspaces between groups.

*Quadratic mean diameter includes trees >= 1" dbh only.

Modeling assumptions: Site Index = 78 (Minor), Stand Density Index (SDI) max = 450

Table 3. Forest Density and Structural Targets (Full Stocking Level, Mixed Conifer PFA)

DESIRED FUTURE CONDITION

Dry Mixed Conifer Forest Type - All Sites - Post-Fledging Family Area

VSS Class	DBH Class	% of Area	Mean DBH	Group basis SDI	Mean Trees/ acre	Basal Area (ft^2/acre)	Canopy Cover (percent)	Per acre basis mean (average acre) Trees/ acre	Basal Area (ft^2/acre)
1	<1	10	0.1	0	203	0		20.3	0
2	1-4.9	10	3	29	200	10		20.0	1
3	5-11.9	20	8.5	140	182	72		36.3	14
4	12-17.9	20	15	145	76	93	60	15.2	19
5	18-23.9	20	21	153	47	112	60	9.3	22
6	24+	20	27	170	34	137	60	6.9	27
								108.0	84
								Dq* =	13.23
								SDI* =	137.4

====== Note on per acre basis =======

Reserve trees and grass matrix areas are included in these figures. Trees are closely grouped, allowing for open interspaces between groups.

*Quadratic mean diameter includes trees >= 1" dbh only.

Modeling assumptions: Site Index = 85 (Minor), Stand Density Index (SDI) max = 486, Species composition = 75% ponderosa pine, 25% Douglas-fir (actual species composition will be project-specific)

Table 4. Forest Density and Structural Targets (Full Stocking Level, Mixed Conifer FA)

DESIRED FUTURE CONDITION

Dry Mixed Conifer Forest Type - All Sites - Foraging Area

VSS Class	DBH Class	% of Area	Mean DBH	Group basis SDI	Mean Trees/ acre	Basal Area (ft^2/acre)	Canopy Cover (percent)	Per acre basis mean (average acre) Trees/ acre	Basal Area (ft^2/acre)
1	<1	10	0.1	0	203	0		20.3	0
2	1-4.9	10	3	29	200	10		20.0	1
3	5-11.9	20	8.5	140	182	72		36.3	14
4	12-17.9	7	15	145	76	93	60	5.1	6
4	12-17.9	13	15	95	50	61	40	6.6	8
5	18-23.9	20	21	123	37	90	50	7.5	18
6	24+	20	27	149	30	120	60	6.0	24
								101.8	72
								Dq* =	12.69
								SDI* =	119.6

====== Note on per acre basis =======

Reserve trees and grass matrix areas are included in these figures. Trees are closely grouped, allowing for open rooting zone interspaces between groups.

*Quadratic mean diameter includes trees >= 1" dbh only.

Modeling assumptions: Site Index = 85 (Minor), Stand Density Index (SDI) max = 486, Species composition = 75% ponderosa pine, 25% Douglas-fir (actual species composition will be project-specific)

as but not limited to potential vegetation type, soil type, climate, successional stage, insect and disease conditions, and fire regime condition class. This information should be incorporated in all silvicultural applications utilizing fundamental knowledge of tree silvics, growth patterns etc. and displayed and quantified where appropriate using metrics such as stand density index, site index, etc.

SILVICULTURAL METHODS AND SYSTEMS

Desired forest conditions for the goshawk food web are described in the MRNG and goshawk guidelines. Attainment and maintenance of these forest conditions can be achieved by applying appropriate silvicultural systems documented in a silvicultural prescription (Graham and Jain 2004). In general the desired forest conditions and suggested forest dynamics inherent within them can be created and maintained using selection systems (Pearson 1950, Long and Smith 2000, Graham and others 2007). However, even though selection systems and silvicultural methods necessary to create and maintain goshawk habitat are slightly different than those aimed at producing commercial timber, the principles and concepts are relevant to selection systems for sustaining goshawk habitat, such as:

- Maintenance of high-forest cover on landscapes at all times (forests and stands have no origin or endpoint).
- Forest regeneration is established following each management entry (cutting cycle) on a scheduled basis.
- Structural regulation and sustainability is provided for at the local and landscape scale and smaller spatial scales (stand, group, clump) are integral to attaining desired landscape conditions (Long and Smith 2000).

The MRNG focuses on creating and sustaining a patchy forest of highly interspersed structural stages ranging from regeneration to old forest throughout a goshawk territory (≈ 2,400 ha, 6,000 acre landscape). These variable density tree groups can be comprised of 2-40 trees occupying up to 1.6 ha (0.1 to 4 acres) but tree groups are generally less than 0.3 ha (0.75 acres). Sufficient growing space between tree groups is required for producing the desired large trees and the canopy densities within tree groups. Depending on the biophysical setting and existing forest structure, occasional openings to 1.6 ha (4 acres) in size may be created, but each regeneration group larger than 0.4 ha (1 acre) must provide for retention of 3-5 mature reserve trees per 0.4 ha (1 acre). The discontinuous, irregular forest structural stage distribution is similar to that maintained by the mature selection system described by Pearson (1950) or the grade selection system described by Meyer (1934). Meyer (1961) perfected the use of "q" defined diameter distributions for sustaining the production of timber. In fact the structural stage distribution defined in the MRNG can be represented by a diameter distribution defined by a "q" of 1.16 (2 inch diameter class basis). Perhaps "individual/clump or clump selection" are appropriate terms that describe the silvicultural system used to sustain goshawk habitat. As Baker (1934) stated there are not four or five silvicultural systems but general classifications that contain a myriad of systems that can be developed to sustain forest conditions to meet management objectives.

The Forest Vegetation Simulator (FVS) is an excellent tool for planning and displaying either group selection or individual tree selection systems (Dixon 2002). It can be calibrated to local conditions and variants are available for most forests. FVS's default individual tree selection and group selection options readily project diameter distributions and tree densities through time; however, FVS has many other options for designing and projecting stand treatments. For example, trees can be selected to leave or remove by species, diameter, height, canopy cover, stand density index, basal area, trees/unit area, crown class, and from inventory plots to name a few. Stand dynamics (i.e., regeneration, growth, death) projected by FVS are readily displayed by the Stand Visualization System (SVS). Because the automatic default in SVS randomly distributes trees, the tree patterns and their juxtaposition will most likely differ from the desired goshawk forest structures displayed in the MRNG. Nevertheless, mapped tree locations or estimated tree locations can be input and used by SVS to display the group/clump distribution inherent to the MRNG. In addition, individual trees can be selected by location within the stand to be left or removed or trees can be selected by characteristics (e.g., diameter, species height etc.) This information can be used to schedule treatments in FVS (see Graham and others 2007, Appendix A for an example of using FVS and SVS for projecting and displaying complex stand structures). In addition the fire and fuel extension

of FVS can readily be used to display fire behavior metrics such as torching and crowning index.

PROJECT PLANNING

Regional management priorities

> "The restoration of the ecological functionality of Southwestern forests and grasslands, with primary emphasis on fire adapted systems, has been identified as the central priority for this Region… Nationally, the Forest Service recently decided that each Region would develop a 5-year, integrated regional strategy outlining how they plan to address designing land management programs that achieve resource-specific objectives and work to create a landscape pattern that effectively lessens the likelihood of large wildland fires." (USDA Forest Service, Southwestern Region, 2004).

Management direction linking this central priority to implementation of the MRNG was stated in a transmittal letter from the Southwestern Regional Forester: "…we have come to understand there is a high level of compatibility between research findings for northern goshawk habitat, ecological restoration, sustainability, and the restoration of fire adapted ecosystems." (Forsgren, 2006).

Forest plan standards: Incorporation of MRNG

In the Southwestern Region, Land and Resource Management Plans (LRMPs) provide the management direction and Standards and Guidelines for the Mexican Spotted Owl (MSO) and other Threatened & Endangered species as well as the northern goshawk (MRNG). Under current Forest LRMPs, most forest types that are not classed as restricted habitat under MSO or management-limited by other specified requirements will be managed under the MRNG strategy. Additionally, 75-80% (depending upon geographic area) of the MSO restricted forest types may be managed under the MRNG strategy, but this is not required under Forest LRMPs. Cutting trees greater than 60 cm ≈ 24 inch diameter at breast height (dbh) is prohibited in Mexican spotted owl restricted habitat (mixed conifer and pine/oak forest types). Consultation with U.S. Department of Interior, Fish and Wildlife Service must be initiated to resolve conflicts when activities conducted in conformance with the MRNG may adversely affect other threatened, endangered, or sensitive species or may conflict with other established recovery plans or conservation agreements.

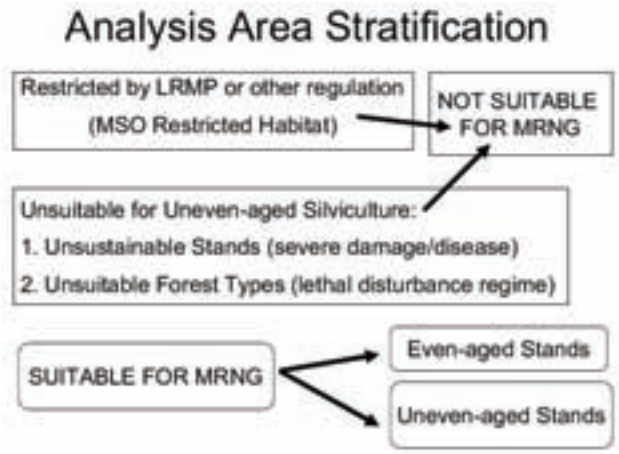


Figure 5. MRNG Forest Stratification Criteria

Project planning is initiated by stratification of an analysis area to classify both plan-level (MSO, other special areas), and bio-physical (forest types, structure, condition, etc.) management stratum. It is critical to identify existing forest conditions that are unsuitable for uneven-aged silvicultural treatments, and to recommend other management alternatives. Examples of unsuitable forest conditions include:

(1) those affected by severe insect, disease, or other damage;

(2) forest types that may experience windthrow damage if openings are created within the stand; and

(3) inappropriate forest types (characteristic lethal fire regime with ecologically-adapted even-aged forest development).

Some forest conditions may be permanently unsuitable for uneven-aged silvicultural treatments (i.e. characteristic lethal fire regime), while other conditions (severe insect, disease, or other damage) may be more appropriately managed with even-aged silvicultural methods during the initial treatment, but in the long-term these areas are suitable for uneven-aged management strategies (planning analysis and stratification flowchart, Figure 5). There are also multiple other decision criteria for selection of appropriate silvicultural systems and methods. Some of the most important are listed below:

- Biophysical setting and/or potential vegetation
- Current condition relevant to both short- and long-term desired condition
- Wildfire hazard/fire regime condition class
- Dwarf mistletoe/other insect-disease conditions

Uneven Aged Foraging Area Summary

Total Stratum

	Number	Acres
Stands in Stratum	87	6853

Based upon Proportional Acres

		Acres
Percent of Stratum in Commercial Conifer	92	5971
Percent of Stratum in Other Species	8	882

Commercial Conifer in Stratum 5971 Acres

(Averages)

VSS	Canopy Cover	Merch Volume - Board Feet	Merch Volume - Cubic Feet	Trees Per Acre	Basal Area	SDI	Proportional Acres	% of Total Comm. Conifer Acres
1	2	193	51	313	4	9	212	4
2	23	1744	400	2496	37	126	174	3
3	36	3345	1040	928	82	195	1033	17
4	46	6661	1475	722	84	178	1293	22
5	51	11370	2255	655	93	189	1938	32
6	54	18532	3300	691	108	210	1321	22

Figure 6. Plot by Plot Spreadsheet Summary, Example Project Analysis Area, Current Condition

- Operability, logging systems, economics, and feasibility of treating
- Regeneration of desired species
- Snags and woody debris

A specific need to manage a stand outside goshawk guidelines must be identified and discussed by an interdisciplinary planning team during project development. Managing outside the guidelines requires a site specific Forest Plan amendment for Southwestern Region National Forests.

Inventory and analysis

The MRNG recommends the targeted vegetative structural stages (VSS, 6 stages) proportions be managed with juxtapositions such that there is a high degree of interspersion of VSS at the sub-stand level. This implies an uneven-aged forest, regulated to provide landscape (2,400 ha ≈ 6,000 acre goshawk territory home range) sustainability.

Sub-stand structural classification of uneven-aged forests poses a challenge relative to stand inventory and analysis for prescription development and planning. Generally, structural stages are determined by which tree component represents the highest basal area. However, even though a big tree may dominate a group's basal area, a predominance of grass/forb/shrub, seedlings, or young forest may determine the VSS (i.e., VSS 1-grass/forb/shrub, VSS 2-seedling/sapling). "The area" in which VSS is determined can be as small as a group of 2 to 3 trees up to stand-sized areas if little diversity is present. As such, depending on the locale, inventory methods, and data needs, it may be more appropriate to classify the vegetation to VSS before quantifying the metrics (see Graham and others, (2007) for methods of classifying VSS). Typical stand exam data is collected at the plot scale and subsequently summarized to the stand. This homogenizes sub-stand structural variability such as VSS distributions and tree group characteristics, etc. A stand-level summary is adequate for one and two-storied stands that will be treated to initiate conversion to future uneven-aged structure, but is inadequate for stands currently composed of three or more VSS classes. One method for analysis of uneven-aged forest sub-stand characteristics is to classify and summarize each sample plot independently. In this way, all uneven-aged stands in the project area can be combined into a stratum and individual plots within a stratum can then be compiled to generate stratum statistics. This method may not perfectly determine VSS distribution but it does provide a sub-stand summary of forest characteristics sufficient for planning and prescription development. The use of fixed-area rather than variable-area sample plots will also provide a better representation of local structural characteristics. In addition, stand maps could be obtained for a few of these fixed area plots and displayed using both FVS and SVS, an excellent communication tool. Other inventory methods such as transects can also provide an overall summary of VSS distribution [see Graham and others (2007) for methods for quantifying and displaying VSS distributions].

The Southwestern Region has developed a methodology for project planning analysis. An analysis area is stratified according to previously-described criteria: forest types by structure/condition (e.g. even-aged/two-aged, uneven-aged, unsustainable stands) are classified and grouped into separate stratum. Standard stand-level summaries are computed to determine current condition for the even-aged/two-aged and unsustainable stands and summarized by stratum. The following process is used to develop current

VSS 5	Uneven Aged Foraging Area			
		Variation		
	Average	Minimum	Maximum	Range
Canopy Cover	51	15	82	67
Mech Volume - Board Feet	11370	1777	50064	48287
Mech Volume - Cubic Feet	2255	365	9548	9183
Trees per Acre	655	20	9733	9713
Basal Area	93	15	334	319
SDI	189	40	600	559

Species Composition (percentage) by Basal Area	
PP	95.38
DF	1.06
WF	0.00
WP	0.00
BS	0.00
ES	0.00
CB	0.00
WS	0.00
LM	0.00
QA	0.56
OH	0.61
CO	0.00
PI	0.91
RM	0.00
BC	0.00
PE	0.00
JU	1.19
AS	0.29
	100.00

Figure 7. Plot by Plot Spreadsheet VSS Classification Statistics, Example

condition statistics for uneven-aged stratum (USDA Forest Service. 2007b):

- Stands are sorted and grouped by goshawk habitat management emphasis (PFA, FA or nest), and each grouping of stands is then aggregated into separate stratum for analysis.
- The exam plot data for each stand are assigned to their respective stratum, and disassociated with individual stands.
- Data for each plot is expanded to a unit area basis, and grown to a common analysis year through the FVS model. Plots comprising a specific stratum are then batch run through FVS. FVS will summarize VSS classification, normal standard summary statistics and computed values for each plot independently.
- FVS individual plot summaries are exported to the PLOT_BY_PLOT excel workbook. Macros in this workbook are used to combine plots by VSS class and display summary statistics for each VSS class. Examples of these summaries are shown in Figures 6 and 7.

Target Stand Conditions

Figure 3 shows the six structural stages and their target distribution for sustaining goshawk habitat, or for that matter sustaining any vegetative community (Odum 1971).

Understanding canopy cover and how it is measured is required for developing the desired goshawk habitat. Moreover, canopy cover recommendations vary depending on goshawk home range components (i.e., nest area, PFA, FA). Canopy cover is defined in MRNG as: "the percentage of a fixed area covered by the crowns of plants delimited by a vertical projection of the outermost perimeter of the spread of the foliage" and is determined at the group or clump level for VSS 4 thru 6 (mid-aged through old forest).

The group and clump nature, especially of native ponderosa pine forests in the Southwest, not only encompasses the area occupied by tree boles and canopies but it also includes areas extending beyond tree crowns that are often occupied by tree roots (Pearson 1950). These areas (primary rooting zones) between tree clumps are free of trees and are occupied by roots of trees within the clump/group. These areas not only provide a rooting zone, they also provide growing space for crown expansion, needle development and other factors that allow trees within groups to develop while the desired relatively high canopy cover within the group is maintained (Figure 8). Therefore, a highly heterogeneous stand containing the entire suite

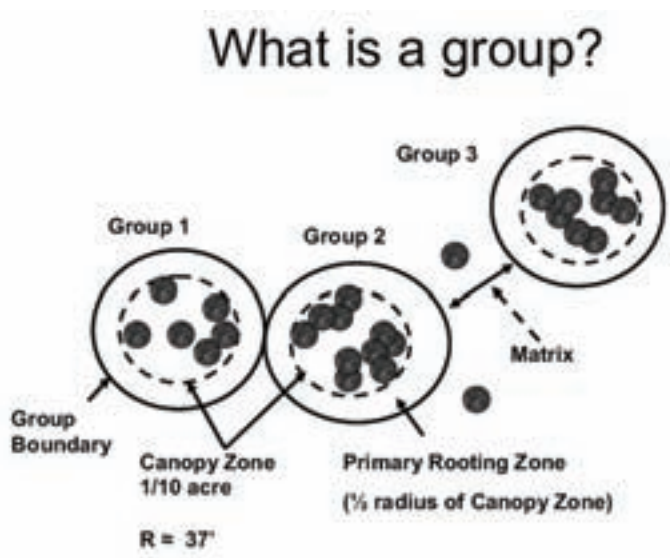


Figure 8. Groups and Group Spacing

of VSS (grass/forb/shrub through old forest) and the open areas occupied by tree roots would be at full site occupancy even though timber management metrics (e.g., stand density index, trees per unit area, basal area) may not indicate these conditions. In addition, by separating the crowns between tree groups and creating and maintaining highly variable forest structures with multiple tree juxtapositions, these conditions reflect the historic conditions and reduce crown fire potential as measured by crowning and torching index. Additional desired conditions include a scattering of large reserve trees (7.4-12.3 per ha ≈ 3- 5 per acre), large snags (4.9 per ha ≈ 2 per acre), large logs (7.4 per ha ≈ 3 per acre), and woody debris (2.2-3.1 Mg per ha ≈ 1965 to 2947 pounds/acre) through the landscape. The forest floor should retain a reasonable amount of down woody debris the amount of which should be commensurate with local site historic conditions and provide for the ability to restore frequent surface fires for ecosystem maintenance.

Prescription Targets

Various threshold target densities for structural groups are recommended in the MRNG for differing forest types and goshawk home range components. Based upon these recommendations, targets have been developed for goshawk PFA and FA for ponderosa pine and mixed conifer forest types. Determination of target canopy cover thresholds during field implementation has been problematic due to various methods used to measure canopy cover and natural variability of forest characteristics. There have also been misunderstandings of the recommended means for measuring canopy cover. Therefore target stocking levels for project implementation have been developed by using the FVS canopy cover model. With this model, stocking levels were developed based on canopy cover and translated to measurable variables such as trees per unit area and basal area (BA) and by VSS class (Tables 1-4). Growth modeling to develop target stocking levels was conducted using the following assumptions:

- The MRNG target canopy cover thresholds for VSS 4-5-6 would be achieved and maintained.
- Target stocking levels for VSS 1-2-3 were developed to provide necessary stocking levels of younger tree age classes to achieve future mid-aged to old tree target size classes/densities.
- Differing site indices were examined for ponderosa pine and dry mixed conifer forest types. No significant stand developmental differences were noted based upon an average site index range, so stocking targets were developed by forest type and goshawk home range component (PFA and FA). (Stocking levels may need to be adjusted for very dry or otherwise poor site locations.)
- Structure and density is maintained by mechanical treatments on a 20-year cycle, and prescribed fire on a 10-20 year cycle.

Projections based on the stand modeling process determined that threshold canopy cover densities could not be achieved nor maintained as a whole stand condition. Therefore, it is recommended that group size be limited to less than 0.2 ha (0.5 acre) on average to sustain the desired canopy cover levels. Primary rooting zones provided growing space necessary to develop and sustain the desired canopy cover within tree groups. Full-stocking level targets were developed with these concepts in mind and are a starting basis for project planning. In the context of MRNG, full-stocking levels are defined as the condition where the forest is patterned as shown in Figure 9. Note that full-stocking in this context is not equivalent to full-stocking as defined by traditional density measurements such as stand density index (SDI).

Many current Southwestern Region projects are focused on RHRC, since there has been a tremendous increase in the number of trees per unit area since the late 1800's. Historic reference conditions are generally less than the full-stocking level MRNG targets for average growing site conditions. On forest sites of above-average growth potential, the historic condition may be greater than the full-stocking level MRNG targets. Sometimes hazardous fuels reduction project objectives cannot be achieved at the full-stocking level. However, the broad objectives of the MRNG can be met at a wide range of forest densities; overall stand density can be reduced or slightly increased from the full-stocking level, while adhering to MRNG sustainability principles. During project implementation, canopy zone separation of tree groups may be adjusted from full-stocking, as long as forest structural sustainability and group canopy cover guidelines are met. If the desired conditions can not be met, a site specific Forest Plan amendment must be prepared. However in most cases, conditions suitable for

both MRNG and project objectives can be met by creation of additional inter-group space (matrix) between rooting zones to achieve a desired average distance between tree canopy zones in adjacent groups (Figure 10). This inter-group space can be described as an additional open area composed of few or no trees. It may be desirable to retain a low density scattering of individual trees throughout this area, both to provide for natural forest patterns, and to provide for long-term development of other structural components (i.e., large/old reserve trees). To facilitate prescription development, a spreadsheet tool has been developed to calculate stand metrics at variable spacing distances between tree group canopy zones (USDA Forest Service, Southwestern Region, 2006). Figure 11 displays the spreadsheet summary data for a ponderosa pine forest type PFA at the full-stocking (100%) level. In this example, the spacing between canopy zones is 37.1 feet (11.3 meters) and the average acre mean target density is 69 square feet basal area (2.6 square meters/hectare). Figure 12 shows the summary data for an adjusted target condition with spacing between canopy zones of 55.5 feet (16.9 meters). In this example, the adjusted average acre mean density target is 51 square feet basal area (1.9 square meters/hectare), representing a resulting stocking density of 74% of

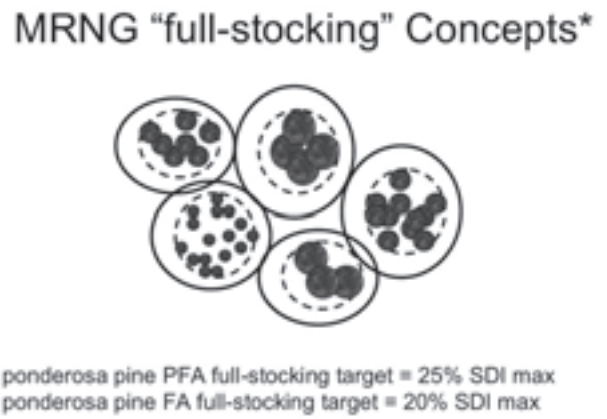
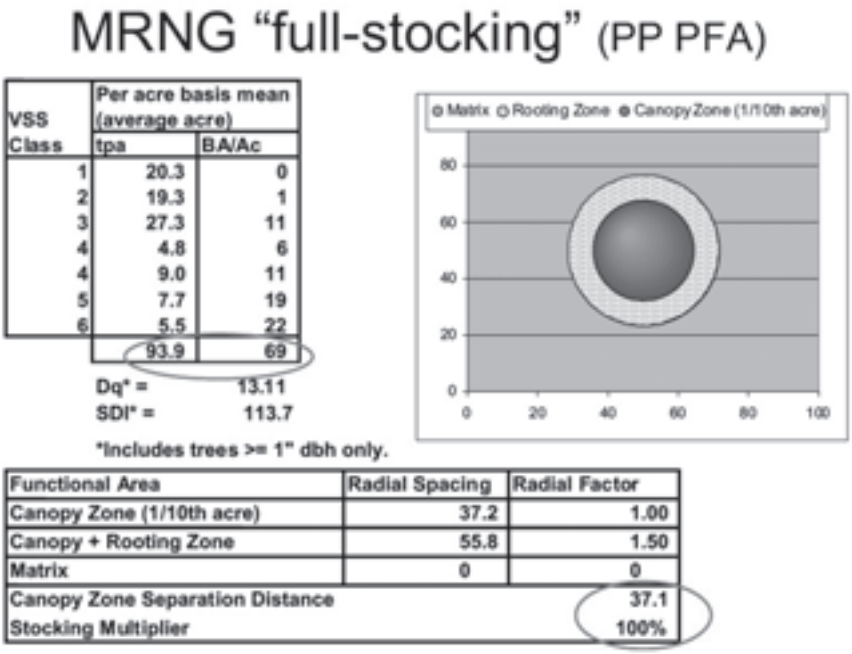


Figure 9. Full-Stocking (Illustration)

Figure 10. Groups and Stand Density Adjustments from Full-Stocking (Illustration)



VSS Class	Per acre basis mean (average acre) tpa	BA/Ac
1	20.3	0
2	19.3	1
3	27.3	11
4	4.8	6
4	9.0	11
5	7.7	19
6	5.5	22
	93.9	69

Functional Area	Radial Spacing	Radial Factor
Canopy Zone (1/10th acre)	37.2	1.00
Canopy + Rooting Zone	55.8	1.50
Matrix	0	0
Canopy Zone Separation Distance		37.1
Stocking Multiplier		100%

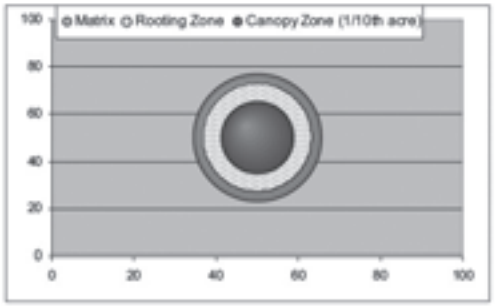
Figure 11. Full-Stocking– ponderosa pine PFA (Spreadsheet Summary)

MRNG Adjusted Stocking (PP PFA)

VSS Class	Per acre basis mean (average acre) tpa	BA/Ac
1	14.9	0
2	14.3	1
3	20.1	8
4	3.5	4
4	6.6	8
5	5.7	14
6	4.0	16
	69.2	51

Dq* = 13.11
SDI* = 83.8

*includes trees >= 1" dbh only.



Functional Area	Radial Spacing	Radial Factor
Canopy Zone (1/10th acre)	37.2	1.00
Canopy + Rooting Zone	55.8	1.50
Canopy + Rooting Zone + Matrix	65.0	1.75
Canopy Zone Separation Distance		55.5
Stocking Multiplier		74%

Figure 12. Groups and Stand Density Adjustments from Full-Stocking (Spreadsheet Summary)

full stocking. Use of this spreadsheet tool facilitates rapid analysis of target stand conditions for project planning. The leave stand characteristics displayed by the spreadsheet can then accompany the marking guide templates to provide implementation instructions to field layout crews.

IMPLEMENTATION

Project Layout

Surveys for goshawks are made within the management analysis area prior to management activities, including an area 0.8 km (0.5 mile) area beyond the boundary. Survey requirements are spelled out in the MRNG. These surveys will help identify nest areas, PFAs, and foraging areas and a requisite spacing of territories across the landscape (3.2 to 4 km ≈ 2 to 2.5 mile). Goshawk Territories are made up of the following components (Figures 1-2):

1) PFA (168 ha ≈ 420 acres total), including 6 nest areas, each 12 ha (≈ 30 acres) in size; 72 ha (≈ 180 acres) minimum of nest areas should be identified within each PFA (six nest sites - three nests are suitable and three are replacements).
2) One Foraging Area = 2,160 ha (≈ 5,400 acres) surrounding the PFA.
3) Total Home Range Size = about 2,400 ha (≈ 6,000 acres).

In summary, planning and management of goshawk territories entails the map delineation of 6 nesting areas (3 potential, 3 replacements), a post-fledgling family areas that encompasses the six nesting areas, all surrounded by the foraging area. A territory with these components is established where there are known nest sites, old nest sites, areas where historical data indicates goshawks have nested in the past, and where goshawks have been repeatedly sighted over a 2-year period. When possible, all historical nest areas should be maintained. Human activity should be limited in nesting areas and PFAs during the breeding season (March 1 through September 30). The remainder of the 2,400 ha (6000 acre) management territory consists shall be managed as foraging areas, according to applicable guidelines

Tree Designation

This management strategy focuses on attainment and monitoring of residual forest characteristics. For these reasons, implementation of project prescriptions would be difficult or impossible without designation by leave tree marking.

General Guides for Marking Even-aged and Two-aged Stands

Stands with these structures cannot be regulated with uneven-aged management systems during initial treatment entries. The following guidelines outline a process for converting these types of stands to uneven-aged structures within the context of MRNG desired conditions.

Initial steps toward conversion to an uneven-aged forest structure:

1. Where some age class diversity is present, leave as many under represented VSS trees, in small groups, as possible.
2. Create openings for VSS 1 age class recruitment (including the primary rooting zones) on approximately 15-20% of project/stand area. Do this by removing entire groups of trees from the predominant age class, but only in those areas with trees of sufficient maturity and vigor to provide adequate seed for

natural regeneration. Diseased (e.g., mistletoe) and damaged trees may be targeted for regeneration, but because these trees are often important elements in forest ecosystems, some may be retained. It is recommended that diseased trees not be retained as seed trees for new VSS 1 groups. Diseased trees can be retained within larger VSS tree groups with other trees of similar height. Diseased trees can also be isolated from younger trees when the desired distances between tree groups is attained. Follow MRNG regarding tree group sizes, opening sizes, reserve trees, downed logs, woody debris, etc.

3. Thin trees to initiate development of greater forest diversity, to create desired forest structural characteristics, and as necessary to meet project-level resource objectives.
   a) Begin to create group structure, including both the canopy and primary rooting zone portions of the group. Initial creation of groups could be referred to as creating doughnuts. The doughnut is the primary rooting zone and the doughnut hole is the canopy zone that is left. These groups should generally be sized from 0.04 to 0.13 ha (≈ 0.1 to 0.3 acre) of various shapes. Once trees within identified primary rooting zones (and the inter-group matrix, if necessary) are removed, thinning of retained groups may be required to grow young trees (VSS 2 and 3) into large trees more rapidly.
   b) Thin VSS 2 and 3 groups to variable densities to accelerate their growth. However, thin VSS 2 and 3 commensurate with attaining the desired interlocking crowns when these tree groups grow into VSS 4-6.
   c) For high-density mid-aged groups that have not been previously thinned, only thin groups to the extent necessary to sustain group maintenance and development, taking care to maintain required canopy cover density. Do not thin VSS 6 groups, except to remove smaller young trees that pose a threat to sustainability of the mature tree group. Do not thin groups such that the structural attributes are altered. Suppressed and damaged trees that have developed with the group are important habitat elements for wildlife species. Squirrels, for example use overtopped trees for nesting. Only thin groups to the extent necessary to maintain desired current and future species composition, sustainability and development.
   d) Areas lacking adequate seed bearing trees will be difficult or impossible to regenerate naturally during an initial management entry. In this situation, accelerating tree growth to larger VSS classes is the primary management objective. Thinning should be prescribed to develop trees within groups that have full live crowns for viable cone production.
4. Create a matrix between tree groups (groups = canopy and primary rooting zones) if less than full stocking is desired, based upon project-level objectives. Maintain matrix (beyond rooting zones) with few or no trees. A matrix is designed to provide for additional spacing between high density canopy zones, beyond that provided by the primary rooting zones.

General Guides for Marking Uneven-aged Stands

Some project areas and ecosystem management areas presently have a mix of VSS classes. These areas can be managed to further develop and maintain desired VSS class diversity. Inventory data at the landscape level is desired to ensure the VSS distribution proportions and juxtapositions are known so the desired structural proportions on the landscape can be developed. By having a landscape view, prescriptions can be developed to ensure the landscape desired condition is planned for and being developed. In order to maintain desired structural proportions on the landscape, it's important to balance structural distribution at the local (stand scale) within larger landscapes. Some local areas could be managed to temporarily provide a disproportionately large percentage of a structural stage that is otherwise limited or lacking in the larger landscape. Any VSS in surplus of the desired percentage may be regenerated to create a future balance of VSS classes. Marking guide templates have been prepared for use as samples for different forest cover types and goshawk habitats in uneven-aged forest conditions, based upon full stocking density targets (USDA Forest Service, 2006b). As previously discussed, stocking levels can be adjusted to meet various management objectives and provide prescription parameters for residual stand desired conditions. A marker's tally form spreadsheet has been developed as a guide to measure attainment of desired structures during marking. Each marker tallies leave tree groups by VSS and group size (1/10 acre basis) during the marking process. This tool summarizes post-marking conditions to provide information on how many acres of each VSS class are being retained as well as the residual percentage of each VSS class over the entire

Marker's Talley Form Spreadsheet Summary

VSS Class	Group Equivalent Acres	Individual Tree Equivalent Acres	Total Equivalent Acres	Percent of Area by VSS Class
VSS 1	5	0	5	4
VSS 2	9	0	9	7
VSS 3	35	3	38	27
VSS 4	58	0	58	41
VSS 5	24	2	26	18
VSS 6	4	2	6	4
Total Acres	134	7	141	100

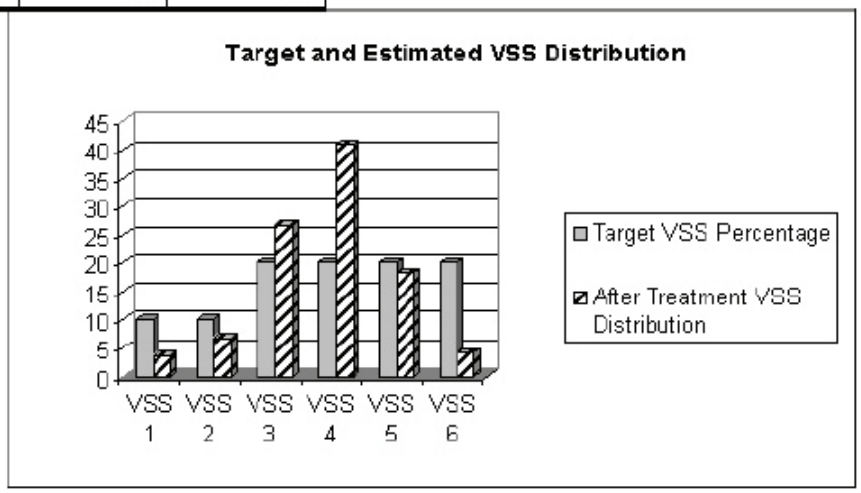


Figure 13. Marker's Tally Form Summary

project area (USDA Forest Service, 2006c) (Figure 13). As such, this tool can be used for both quality control and as monitoring documentation.

CONCLUSION

The goal of silviculture is to develop vegetation management strategies to meet desired conditions (silvicultural systems- a planned series of treatments through the life of a forest) and to document them in silvicultural prescriptions to meet management objectives. The Southwestern Region is committed to restore the historic resilience and function of fire adapted (ponderosa pine and dry mixed conifer) forests and is committed to develop and maintain habitat for both the Mexican spotted owl and the northern goshawk through a Regional Amendment of Forest Plans. Management recommendations for the northern goshawk, ecological restoration research, ponderosa pine management information, and fire hazard and fuel treatment information are only a partial list of science that can be used to inform the management actions (silvicultural treatments) in the Southwestern Region (Reynolds and others 1992, Covington and Moore 1994, Pearson 1950, White 1985). Through this effort we have been able to establish a strong link between restoring historic conditions and implementing the MRNG. However, this information in most circumstances is inadequate for planning and executing on-the-ground activities. Therefore the Southwestern Region developed tools that could help planners, silviculturists, fuels specialists, and others involved with designing and implementing treatments directed at restoring fire adapted forests of the Southwest. These tools and the MRNG both provide a template, a process, and approach that are adaptable to a wide variety of forests and a wide variety of management

objectives. We do not postulate that the exact metrics in the MRNG or those presented in spreadsheet tools are precisely applicable to other locales. However, we argue the tools and procedures have sufficient flexibility to allow project planners to incorporate other objectives.

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