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Defining old-growth Douglas-fir forests of central Montana and use of the northern goshawk (Accipiter gentilis) as a management indicator species

Thomas C. Whitford

The University of Montana

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DEFINING OLD-GROWTH DOUGLAS-FIR FORESTS OF CENTRAL MONTANA AND USE OF THE NORTHERN GOSHAWK (*Accipiter gentilis*) AS A MANAGEMENT INDICATOR SPECIES

by

Thomas C. Whitford

B.S., University of Montana, 1986

Presented in partial fulfillment of the requirements for the degree of Master of Science

UNIVERSITY OF MONTANA

1991

Approved by:

E. Earl Willard
Chairman, Board of Examiners

Date

July 10, 1991

Dean, Graduate School
Old-growth Douglas-fir (Pseudotsuga menziesii var. glauca) forest stands and Douglas-fir northern goshawk (Accipiter gentilis) nest stands were investigated in summers 1989 and 1990. Data were collected from 21 old-growth stands and 12 goshawk nest stands. Objectives of this study were to recommend refinements to an old-growth forest definition used by the Lewis and Clark National Forest (LCNF), to compare old-growth Douglas-fir stands with Douglas-fir goshawk nest stands in order to evaluate the appropriateness of the goshawk as a management indicator species (MIS) for old-growth Douglas-fir forests on the LCNF, and to examine the applicability of the nesting habitat portion of a goshawk habitat suitability model for the LCNF. Results indicated that old-growth Douglas-fir stands could be identified with minimum age and minimum dbh used as descriptors. Hence, simplification of old-growth definitions and development of definitions for each forest type were recommended for the LCNF. Differences between old-growth Douglas-fir stands and Douglas-fir goshawk nest stands were significant. The northern goshawk was a poor old-growth forest MIS on the LCNF. Land managers must identify a valid old-growth MIS or employ other methods in order to identify and manage old-growth forests. Index values produced by the goshawk habitat suitability model for each old-growth stand and goshawk nest stand verified that the model was successful in rating the nest stands higher than the old-growth stands. However, index values were virtually impossible to interpret so further refinement is necessary if the model is to be useful.
FORWARD

The chapters of this thesis are designed to be read independently. Because of this, the reader will encounter some redundancy in the methods and study area descriptions of these chapters.

Many people helped in making this project both possible and enjoyable. My thanks go to Dr. Earl Willard, my committee chairperson, for his guidance throughout the project. I am especially grateful for the advice, generosity, and friendship of Dr. Sallie Hejl. I thank the other members of my committee, Dr. Les Marcum and Dr. James Habeck, for their suggestions and review of the thesis.

Appreciation goes to Dr. David Patterson for his help in the matters of numbers. The support and encouragement of Don Sasse, Don Godtel, and other personnel of the United States Forest Service was appreciated.

I thank Dr. Jack Lyon for a place and means to analyze data and write. Gratitude goes to fellow wildlife graduate students for their humor and support.

Finally, I thank my parents, Tom and Patricia Whitford, who provided a firm foundation for me to build on.

Funds for this research were provided by the Lewis and Clark National Forest.
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Chapter One:

CHARACTERIZATION OF

OLD-GROWTH DOUGLAS-FIR FORESTS

OF CENTRAL MONTANA

INTRODUCTION

No environmental issue in several decades has attracted more attention or created more controversy in the northwestern United States than harvesting the region's old-growth forests (Orians 1990). Loss of old-growth forests to human activity and manipulation has become an escalating concern to natural resource organizations and the general public. Despite this concern, old-growth forests have been virtually "liquidated" within private land holdings (Juday 1978, Debell and Franklin 1987, Orians 1990). Fortunately, examples of old-growth forests remain intact in national parks, wilderness areas, and some national forests (Debell and Franklin 1987, Greene 1988, Habeck 1988, Orians 1990). Conscientious management of the remaining old-growth forests is of vital importance because, if current harvesting practices continue, all existing old-growth forest stands not protected by national parks or wilderness areas will have been logged by the year 2010 (Orians 1990).

Old-growth forests serve many important functions. They provide habitat for a variety of plant, fish, and wildlife species; maintain
water quality, soil productivity, and soil stability; and supply
recreational opportunities (Juday 1978, Barrows 1984, Yuskavitch 1985,
Habeck 1988, Greene 1988, Thomas et al. 1988, Franklin and Spies 1989,
Miner 1989). In addition, old growth is often recognized as having its
own intrinsic value (Juday 1978, Barrows 1984, Yuskavitch 1985, Habeck

The term "old growth" is commonly used today, but little was known
about old-growth forest ecosystems until the last decade. Much
information addressing its structure, vegetative composition, site
characteristics, and ecological role remains unknown (Spies and Franklin
1988). Such knowledge is essential to devise resource management
prescriptions and forest management plans, which are required for all
national forests by the 1976 National Forest Management Act.

Establishing a definition of old-growth forest has been of
particular interest to the U.S. Forest Service in recent years. Old
growth has been defined in many ways, but a clear definition that is
universally accepted and applied has not been established (Hunter
1989). Developing a definition that is applicable to a large geographic
area may be impossible. Recently, the U.S. Forest Service (1989)
proposed a generic definition of old-growth forests: "Old-growth
forests are ecosystems distinguished by old trees and related structural
attributes. Old growth encompasses the later stages of stand
development that typically differ from earlier stages in a variety of
characteristics which may include tree size, accumulations of large dead
woody material, number of canopy layers, species composition, and
ecosystem function". The definition also stresses that specific
structural characteristics which make up an old-growth forest will vary widely according to forest type, climate, site conditions, and natural disturbance regime. In addition to the generic definition, site-specific working definitions and structure-oriented descriptions of old growth are possible and necessary for old-growth forest management (Thomas et al. 1979, 1988; Alabeck 1982; Heinrickes 1983; Franklin and Spies 1984, 1989).

Resource managers of the Lewis and Clark National Forest (LCNF) have incorporated the following definition of old-growth forest into their 1986 Forest Plan:

Old-growth forest is widely considered to be an essential habitat component for a particular group of wildlife species. However, a standard definition of "old growth" is not available due to great variations in site productivity, species composition, stand history and other variables. Standard criteria used in timber management to classify mature and overmature stands such as age, volume, and culmination of mean annual increment are not good indicators of old-growth forest on the Lewis and Clark National Forest:

An old-growth forest will normally contain the following characteristics:

- One or more coniferous species which are climax or long-lived seral dominants on the site.
- Two or more layers or age classes.
- A combined overstory-understory tree canopy closure which averages 60 percent or more.
- The dominant tree component generally exceeds 13 inches dbh, 50 feet in height, and has reached or is past full maturity with signs of decadence present and obvious.
- At least 2 snags/acre of 10 inches dbh or greater.
- Sparse understory shrub and herbaceous vegetation with logs and other down material common and well distributed through the stand.

The definition was based primarily on extrapolated and modified information derived from old-growth forest stands in Oregon and Washington (D. Godtel pers. comm.). This definition may have limited
applicability to the LCNF (D. Godtel pers. comm.). The definition is general and untested.

Neither a working definition nor a structural description specific to the old-growth Rocky Mountain Douglas-fir (Pseudotsuga menziesii var. glauca) community in central Montana had been created when this study began in 1989, even though this community is scheduled to receive substantial timber harvest in the next decade. Resource managers of the Lewis and Clark National Forest are interested in learning how to describe old-growth Rocky Mountain Douglas-fir forests of central Montana. The objective of this study is to recommend refinements to the current Forest Plan’s ecological definition of old-growth Douglas-fir forests on the Lewis and Clark National Forest.

STUDY AREA

Field work was conducted on the Jefferson Division of the Lewis and Clark National Forest in central Montana during summers 1989 and 1990. Study sites were located in the Little Belt, Big Snowy, Castle, and Crazy Mountain ranges (Figure 1). These mountain ranges display varying topography, with elevations from 1,500 m to 2,800 m. Foothills are generally rolling grasslands with bands of Douglas-fir or ponderosa pine (See Appendix A for plant scientific names). Mid-elevation slopes are primarily vegetated with dense stands of lodgepole pine or Douglas-fir. Grassy benches or forest/grassland mosaics are common throughout the lower and middle elevations. Higher elevations generally have steep
slopes with gentle to flat ridges. Limber pine, whitebark pine, Engelmann spruce, subalpine fir, and grassland are the dominant vegetation types of the upper elevations.

These mountain ranges are characterized by distinct fire histories that are illustrated by the fire-generated or fire-perpetuated forest types dominating the areas (Habeck 1988). Historically, lodgepole pine stands experienced stand-replacing fires, and ponderosa pine/Douglas-fir stands along the forest-grassland ecotone have been maintained by low intensity fires (Habeck 1988). Fire disturbances may play a vital role in maintaining some old-growth forests of central Montana.
METHODS

In summer 1989, I identified 50 old-growth Douglas-fir stands in my study area. Criteria for the stand to be considered a study site were: (1) stand was dominated by Douglas-fir, (2) dominant Douglas-fir trees were large diameter for this species in this geographic area \([\geq 25 \text{ cm diameter-at-breast-height(dbh)}]\), (3) no timber harvesting had occurred in the stand, and (4) stands were at least 2 hectares (5 acres) in size. Data sources for identification of candidate old-growth Douglas-fir stands were aerial photographs, timber stand exam data, and locations from Forest Service field crews and other personnel.

In summer 1990, I randomly selected 25 old-growth Douglas-fir study stands to be sampled from the 50 which met the criteria. Time and weather permitted me to sample only 24 of these study sites. Nineteen study stands were located in the Little Belt, three in the Big Snowy, one in the Castle, and one in the Crazy Mountains (Figure 1). Each old-growth study site was sampled with a series of five fixed-radius plots. Plot locations were determined by a random sampling design (example in Figure 2). A line transect with five evenly spaced points bisected each sample stand as determined by use of aerial photographs. Transect length and distance between points varied with the dimensions of each stand. Stand sizes were calculated by using orthophoto quads and Digitablet 2400 by Numonics. The transect was located so that a majority of the stand fell within its reaches. The starting point of the transect was determined by choosing a random distance from 0 to 100
meters. All random distances came from a random numbers table. Once
the random starting point was determined, five evenly spaced points were
placed on the transect after the starting point. From each of the five
points, a perpendicular, random distance (-50 to 50 m) to a sample plot
center was taken. Positive and negative values corresponded to right
and left directions from the transect point. Only random numbers which
selected plots within the old-growth stand were used. The transect
approach attempted to reduce the likelihood of concentrating the sample
plots in specific areas of the stands. Therefore it allowed me the
opportunity to sample portions of the entire stand.

The stands were sampled using circular plots with radii of 11.3 m
(area = 0.04 ha) and 4.6 m (area = 0.007 ha). Primary old-growth
characteristics were measured on the 0.04 ha plots and secondary
old-growth characteristics were measured on the 0.007 ha plots. Three
0.007 ha plots were nested concentrically inside the first, third and
fifth plots of the 0.04 ha plots (Figure 2).
Physiographic data was taken at plot center of each 0.04 ha plot (elevation, slope, aspect, and habitat type (Pfister et al. 1977).)

Trees, snags, and downed logs were considered primary old-growth stand components. Trees (>20 cm dbh), snags (> 10 cm dbh), and downed logs (>10 cm bottom diameter) were measured and characterized on the 0.04 ha plot. Species (if possible), height and dbh were recorded for trees and snags. Heights were estimated after a few heights were measured at each plot. I recorded percent canopy cover and descriptions of snags and logs such as snag condition (after Cline et al. 1980, see Appendix B), and log condition (after Thomas et al. 1979, see Appendix
The two largest (>20 cm dbh) Douglas-fir trees in each of the 0.04 ha plots were cored and aged. If two large Douglas-fir trees were not located in the plot, large trees (>20 cm dbh) closest to the plot were used. Volume of downed logs (>10 cm bottom diameter) in the 0.04 ha plots was estimated by measuring log length and the log's top and bottom diameters. Volume was calculated using the frustrum of a cone formula (J. Brown pers. comm.).

Small trees, seedlings, shrubs, tree canopy, and ground cover types were considered secondary old-growth components. Trees (0-20 cm dbh), seedlings (>50 cm tall) and shrubs (>50 cm tall) were tallied by species on the 0.007 ha plots. Tree canopy, seedling, shrub, and ground cover were calculated, on the first, third, and fifth 0.04 ha plots, using a method developed by Hejl (1989). Seven points, placed at 0.0, 3.9, 6.0, 7.5, 8.7, 9.8, and 10.8 m intervals, were located in each cardinal direction (N, E, S, and W) from plot center. The type of cover and species were noted after sighting upward and downward from each point. Percent cover was calculated by multiplying the number of points blanketed by each cover type by four. Ground cover types were litter, rock, soil, downed wood, grass, forb, water, and other.

Overall mean values, 95% confidence intervals, and ranges were calculated using the averages for each variable by stand (N = 21).
RESULTS

Age Data

A total of 126 trees were aged. The ages ranged from 70 to 456 years. Overall mean live tree age was 268 years with a 95% confidence interval of 231.7 to 304.3. Diameter (dbh) of the aged trees averaged 48 cm with a 95% confidence interval of 17.8 to 20.2. Seven of the 24 stands had mean ages less than 200 years. Four of these stands had small diameter trees that were aged, but those trees with dbhs \( \geq 36 \) cm were over 200 years. Large, old trees were common on these four stands but were missed on the sample plots. The other three stands had trees \( \geq 36 \) cm dbh that were aged (except one 33 cm dbh tree) and most of these were less than 200 years. Because these latter three stands contained large diameter, young trees, they were not considered old growth and were not included in the overall analysis. Appendix D presents summary statistics from these three forest stands. Appendix E presents summary data, using mean values, from the 21 old-growth study stands.

Physiographic Data

Old-growth stand elevations averaged 1990 m and ranged between 1,695 m and 2,265 m. Stand slope averaged 32% and ranged from 7 to 80%. Old-growth stand orientations were well distributed between each primary compass direction: north, east, south, and west. Recorded habitat types (Pfister et al. 1977) varied widely, covering the range
within the *Pseudotsuga menziesii* series but included other climax series habitat types as well. A complete list of all recorded plant species is in Table 1 (See Appendix A for scientific names).

**Primary Old-Growth Stand Components**

**Live trees.** A total of 1,395 trees (> 20 cm dbh) were sampled on the study sites, 1,217 (87%) of which were Douglas-fir. Stem diameters (dbhs) ranged from 20.0 cm to 94.0 cm. Mean dbh was 36.0 cm, with a 95% confidence interval of 34.5 to 37.5 (Table 2). Large tree densities, by stand, ranged between 85 and 205 per 0.4 hectare (0.4 ha = 1.0 acre). Average large tree density was 130 per 0.4 ha with a 95% confidence interval of 116.5 to 143.5. Mean percent canopy cover was calculated for each old-growth stand. Mean canopy cover ranged from 41% to 77% with an overall mean of 55%. A 95% confidence interval for mean canopy cover was 50.2% to 59.8%.
Table 1. List of recorded plant species and numbers in each measured group. Species are listed according to prevalence.

<table>
<thead>
<tr>
<th>Plant Species</th>
<th>Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Large</td>
</tr>
<tr>
<td><strong>Tree Species</strong></td>
<td></td>
</tr>
<tr>
<td>Douglas-Fir</td>
<td>1217</td>
</tr>
<tr>
<td>Lodgepole Pine</td>
<td>64</td>
</tr>
<tr>
<td>Engelmann Spruce</td>
<td>52</td>
</tr>
<tr>
<td>Subalpine Fir</td>
<td>35</td>
</tr>
<tr>
<td>Ponderosa Pine</td>
<td>21</td>
</tr>
<tr>
<td>Limber Pine</td>
<td>6</td>
</tr>
<tr>
<td>Western Redcedar</td>
<td>0</td>
</tr>
<tr>
<td>Mountain Maple</td>
<td>0</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>1395</td>
</tr>
<tr>
<td><strong>Shrub Species</strong></td>
<td></td>
</tr>
<tr>
<td>Common Snowberry</td>
<td>---</td>
</tr>
<tr>
<td>Common Juniper</td>
<td>---</td>
</tr>
<tr>
<td>Mountain Gooseberry</td>
<td>---</td>
</tr>
<tr>
<td>White Spiraea</td>
<td>---</td>
</tr>
<tr>
<td>Buffaloberry</td>
<td>---</td>
</tr>
<tr>
<td>Wood's Rose</td>
<td>---</td>
</tr>
<tr>
<td>Blue Huckleberry</td>
<td>---</td>
</tr>
<tr>
<td>Mountain Snowberry</td>
<td>---</td>
</tr>
<tr>
<td>Chokecherry</td>
<td>---</td>
</tr>
<tr>
<td>Ninebark</td>
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</tr>
<tr>
<td>Elderberry</td>
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</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Other Recorded Species</strong></td>
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<td>Creeping Oregon Grape</td>
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<td>Kinnikinnick</td>
<td>---</td>
</tr>
<tr>
<td>Red Raspberry</td>
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</tr>
<tr>
<td>Twinflower</td>
<td>---</td>
</tr>
<tr>
<td>Dogwood</td>
<td>---</td>
</tr>
</tbody>
</table>

\(a\) Trees > 20 cm dbh.
\(b\) Trees 0-20 cm dbh.
\(c\) Seedlings 50 cm > 0 \(< 137\) cm in height.
\(d\) Shrubs \(> 50\) cm in height.
\(e\) Plant species noted but numbers were not counted.

**Snags.** A total of 481 coniferous snags (\(\geq 10\) cm dbh) were sampled.

Stem diameters (dbhs) ranged from 10 cm to 89 cm. Mean snag dbh was 28 cm with a 95% confidence interval of 24.4 to 31.6 (Table 2). Snag heights ranged between 1.2 m and 27.0 m. Snag heights averaged 8.2 m.
with a 95% confidence interval of 7.7 to 8.7. Snag densities, by stand, ranged between 15.0 and 105.0 snags per 0.4 ha (Table 2). Average snag density was 45.0 per 0.4 ha with a 95% confidence interval of 35.0 to 55.0.

Snag decomposition classes used were described by Cline et al. (1980) (Appendix B). Of snags recorded on each old-growth stand, an average of 25% were assigned to decomposition class 1, 24% to class 2, 23% to class 3, 21% to class 4, and 7% to class 5.

Downed logs. A total of 2,167 downed logs (> 10 cm bottom diameter) were tallied across all stands. Mean log density, calculated by stand, was 195.0 per 0.4 ha with a 95% confidence interval of 151.0 to 239.0 (Table 2). Log densities ranged from 35.0 to 385.0 per 0.4 ha. Average downed log volume, again calculated by stand, was 100.0 m$^3$ per 0.4 ha. The 95% confidence interval was 72.0 to 128.0. Average downed log volumes ranged between 4.0 and 166.0 m$^3$ per 0.4 ha.

Downed log decomposition classes used were described by Thomas et al. (1979) (Appendix C). Of downed logs measured on each old-growth study site, an average 3% were assigned to decomposition class 1, 13% to class 2, 40% to class 3, 25% to class 4, and 17% to class 5.
Secondary Old Growth Components

Tree canopy. The number of canopy layers was not measured in this study. However, the occurrence of two or more canopy layers can be noted for an old-growth stand based on the assumption that when small and large diameter trees occur together, two or more canopy layers are present in the stand. Therefore, those sample stands with at least 10 small trees (0-20 cm dbh) and 10 large trees (> 36 cm dbh (mean tree dbh)) recorded were tallied as old-growth forest stands with more than one canopy layer. A total of 13 of 21 (62%) sample old-growth stands exhibited more than one canopy layer.

Shrubs. Mean percent shrub cover, calculated by stand, was 16% with a 95% confidence interval of 10.6 to 21.4 (Table 2). Percent shrub cover ranged between 0.0 and 51.0%. A total of 1,555 shrubs (> 50 cm in height) were tallied on the study sites. Using mean shrub densities for each sample stand, shrub density averaged 715.0 per 0.4 ha. The 95% confidence interval was 287.4 to 1,142.6. Densities ranged between 41.0 to 4,235.0 per 0.4 ha.

Small trees. A total of 457 small trees (0-20 cm dbh) were tallied. Small tree densities, by stand, averaged 206 small trees per 0.4 ha (Table 2). The 95% confidence interval for small tree density was 31.4 to 380.6. Densities ranged from 0.0 to 1,787.5 small trees per 0.4 ha.
Seedlings. A total of 963 seedlings (50 to 137 cm in height) were tallied across the stands. Average seedling density, by stand, ranged from 0.0 to 2,213.8 per ha (Table 2). Mean seedling density was 413.0 per 0.4 ha with a 95% confidence interval of 168.2 to 657.8.

Ground cover. A total of 1,532 ground cover recordings were taken, 502 (34%) were recorded as litter, 436 (29%) as forb, 233 (15%) as downed wood, 216 (14%) as grass, 110 (7%) as other (moss, lichen, and seedlings), 27 (2%) as rock, and 8 (1%) as soil.

Table 2. Primary and secondary old-growth study stand components.

<table>
<thead>
<tr>
<th>Component</th>
<th>N</th>
<th>X</th>
<th>95% CI</th>
<th>Range</th>
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<tbody>
<tr>
<td>Live trees</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>dbh</td>
<td>21</td>
<td>36.0</td>
<td>36.0 ± 1.5</td>
<td>20.0-94.0</td>
</tr>
<tr>
<td>height</td>
<td>21</td>
<td>17.0</td>
<td>17.0 ± 0.2</td>
<td>6.0-34.0</td>
</tr>
<tr>
<td>age</td>
<td>21</td>
<td>268.0</td>
<td>268.0 ± 36.3</td>
<td>70.0-456.0</td>
</tr>
<tr>
<td>no./0.4 ha</td>
<td>21</td>
<td>130.0</td>
<td>130.0 ± 13.5</td>
<td>85.0-205.0</td>
</tr>
<tr>
<td>Snags</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>dbh</td>
<td>21</td>
<td>28.0</td>
<td>28.0 ± 3.6</td>
<td>10.0-89.0</td>
</tr>
<tr>
<td>height</td>
<td>21</td>
<td>8.2</td>
<td>8.2 ± 0.5</td>
<td>1.2-27.0</td>
</tr>
<tr>
<td>no./0.4 ha</td>
<td>21</td>
<td>45.0</td>
<td>45.0 ± 10.0</td>
<td>15.0-105.0</td>
</tr>
<tr>
<td>Downed logs</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>no./0.4 ha</td>
<td>21</td>
<td>195.0</td>
<td>195.0 ± 44.0</td>
<td>35.0-385.0</td>
</tr>
<tr>
<td>vol/log</td>
<td>21</td>
<td>0.8</td>
<td>0.8 ± 0.15</td>
<td>0.02-11.6</td>
</tr>
<tr>
<td>vol/0.4 ha</td>
<td>21</td>
<td>100.0</td>
<td>100.0 ± 28.0</td>
<td>4.0-166.0</td>
</tr>
<tr>
<td>Trees</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>canopy cover^g</td>
<td>21</td>
<td>55.0</td>
<td>55.0 ± 4.8</td>
<td>41.0-77.0</td>
</tr>
<tr>
<td>Shrubs</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>cover</td>
<td>21</td>
<td>16.0</td>
<td>16.0 ± 5.4</td>
<td>0.0-51.0</td>
</tr>
<tr>
<td>no./0.4 ha</td>
<td>21</td>
<td>715.0</td>
<td>715.0 ± 427.6</td>
<td>41.0-4,235.0</td>
</tr>
<tr>
<td>Small trees</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>no./0.4 ha</td>
<td>21</td>
<td>206.0</td>
<td>206.0 ± 174.6</td>
<td>0.0-1,787.5</td>
</tr>
<tr>
<td>Seedlings</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>no./0.4 ha</td>
<td>21</td>
<td>413.0</td>
<td>413.0 ± 244.8</td>
<td>0.0-2,213.8</td>
</tr>
</tbody>
</table>

\(a\) All diameters were measured in centimeters.

\(b\) All heights were measured in meters.

\(c\) Age was in years.

\(d\) All densities were in numbers per 0.40 ha (1.0 acre).

\(e\) Covers were expressed in percentages.

\(f\) Volume was expressed in square meters per 0.4 ha.
Comparison of Old Growth Study Results and Old Growth Specifications Currently Used

All 21 of the old-growth study sites fulfilled the currently used old-growth criteria of containing one or more dominant coniferous species which are climax or long-lived seral dominants. However, a total of 13 of the 21 (62%) old-growth sites displayed two or more canopy layers or age classes. Therefore, single canopy layered old-growth Douglas-fir stands were not uncommon, as 38% (8/21) of the study stands had single canopy layers.

The tree canopy closure for the old-growth sample stands averaged 55%, which fell short of the ≥ 60% parameter of the currently used old-growth specifications. In fact, only 7 of 21 stands (33%) had mean canopy closures of 60% or more.

A total of 48% of the measured trees exceeded 33 cm (13 inches) dbh and 52% were greater than or equal to 15 m (50 feet) in height. Overall, approximately 50% of the old-growth sample stands met the currently used criteria where dominant trees generally exceeded 33 cm (13 inches) dbh and 15 m (50 feet) in height.

Indicated by the densities of snags and downed logs, decadence was present and obvious in all 21 old-growth stands. Fifty-two percent of the recorded snags were classified in decomposition classes three, four, and five (Appendix B). Eighty-eight percent of the recorded logs were classified in decomposition classes three, four, and five (Appendix C).

All sample old-growth stands except 3 (14%) had at least two snags per 0.4 ha (1.0 acre) of 25cm (10 inches) dbh or greater. In fact the
old-growth stands averaged 20 snags per 0.4 ha of this size class with a 95% confidence interval of 15.0 to 25.0.

Contrary to currently used old-growth specifications, a variety of shrubs were common and herbaceous plants were very common throughout the old-growth study sites.

Downed logs, woody debris, and litter were common throughout all of the old-growth stands. Table 3 contains the comparison of the currently used old-growth standards and those derived from this study.

Table 3. Comparison of values used in current LCNF old-growth definition and those resulting from this study.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Currently Used Value</th>
<th>Study Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Climax or long-lived seral dominants</td>
<td>≥ 1 species present</td>
<td>≥ 1 species present</td>
</tr>
<tr>
<td>Canopy layers or age classes</td>
<td>≥ 2</td>
<td>13/24 (54%) stands</td>
</tr>
<tr>
<td>Canopy closure</td>
<td>X ≥ 60%</td>
<td>X = 55%</td>
</tr>
<tr>
<td>Dominant trees</td>
<td></td>
<td></td>
</tr>
<tr>
<td>dbh height decadence</td>
<td>X ≥ 13 inches X ≥ 50 feet present and obvious</td>
<td>X = 14 inches X = 56 feet present and obvious</td>
</tr>
<tr>
<td>Snags</td>
<td>2 ≥ 10 in. dbh/acre</td>
<td>X = 5 snags 10 in. dbh/acre</td>
</tr>
<tr>
<td>Shrub and herbaceous veg.</td>
<td>sparse</td>
<td>common</td>
</tr>
<tr>
<td>logs and downed material</td>
<td>common and well distributed</td>
<td>common and well distributed</td>
</tr>
</tbody>
</table>
All old-growth sample stands fully met the following parameters of currently used old-growth criteria: presence of one or more coniferous species which are climax or long-lived seral dominants, dominant trees exceed 33 cm dbh and 15 m in height, signs of decadence present and obvious, at least 2 snags per 0.4 ha of 25 cm dbh or greater, and logs and other downed material common and well distributed. Parameters not met were two or more layers or age classes, tree canopy closure that averages 60 percent or more, and sparse understory shrub and herbaceous vegetation.

DISCUSSION AND MANAGEMENT IMPLICATIONS

Old-growth forests are difficult to define. When establishing a usable definition, one needs to consider the variables that are likely to have ecological significance as well as being easily measured. With a basic understanding of a specific forest type, land managers need to consider the logical criteria on which to base a area and forest type specific old-growth definition. Important factors that must be addressed are the number of descriptors to be included in the definition and how narrow or flexible they are.

As expected, there are good aspects and bad aspects to old-growth definitions that are narrow or flexible. One advantage of a definition with flexible descriptors would be that old-growth forests could be "created" in areas where they are rare or nonexistent by allowing existing forests to develop into old growth with time (Hunter 1989). In this manner, those stands meeting the minimum requirements of a flexible
definition can be preserved and allowed to evolve into a "true" old-growth stand. Another advantage of a flexible definition is that forest stands representing early, middle, and late old growth stages could be identified and preserved. A disadvantage of a flexible definition is that the amount of remaining old growth in an area may be over-estimated. This may lead land managers to believe that current harvest rates are acceptable when in fact they might be too high for sustained yield management practices.

Advantages and disadvantages of old-growth definitions with narrow descriptors also occur. Possibly the "best" old-growth stands will be identified and preserved when implementing a narrow definition, therefore eliminating or reducing over-estimation errors. A disadvantage of a narrow definition is that representative stands of early, middle, and late old-growth stages may not be preserved. Consequently, the number and variety of plant and animal species that inhabit or utilize old-growth forest ecosystems would possibly be reduced. Narrow definitions may also reduce the possibility of "creating" old-growth stands (Hunter 1989) in areas where they are rare or nonexistent. Obviously, care must be taken when creating old-growth forest definitions.

After working with several different Forest Service and private industry data gathering crews, I firmly support the simplistic approach of data gathering designs, especially after utilizing information stemming from different sources. The primary advantage of this approach is that it reduces biased information, especially since in most cases the information is supplied by individuals with varying backgrounds.
Undoubtedly it is difficult, if not impossible, to link a specific list of criteria to encompass all old-growth forest stands found in even a small area. Fortunately all the old-growth study sites had two parameters in common: they all supported large diameter, old trees. With this fact in mind, I propose that old-growth Douglas-fir forest definition on the Lewis and Clark National Forest be based primarily on the number of live trees of a specific dbh per unit area. These dominant trees must be at least 200 years.

The principal justification for such reasoning is that all structural characteristics of old-growth forests were linked to age, and the presence of large diameter trees was a reflection of age (> 200 years) in this study. Therefore if large, old trees are present, other old-growth structural attributes will theoretically evolve with time. Development of large diameter trees in central Montana is truly the time-consuming factor. Second, a major purpose of old growth definitions is to provide a standard criteria for land managers to identify old-growth stands and subsequently to formulate old-growth management strategies. Finally, a usable definition should be as simple as possible in order to limit implementation costs, bias, and confusion.

On the LCNF, old-growth forest definitions should be broken down by forest types and when necessary site conditions which can be deliniated through habitat types. For the Douglas-fir forest type (Table 4) further breakdown is unnecessary because there were no pronounced structural differences between old-growth Douglas-fir forests representing different Habitat Types (site conditions) in this study. Lower values from the 95% confidence intervals, calculated for the
variables measured in this study, were used to define old-growth Douglas-fir forests. Sample old-growth stands averaged 74 trees ≥ 34 cm dbh (low CI value for live tree dbh) per 0.4 hectare with a 95% CI of 62 to 86. Tree ages averaged 268 years with a 95% confidence interval of 232 to 304. Therefore, old-growth Douglas-fir forests will contain a minimum of 62 live trees ≥ 34 cm dbh per 0.4 hectare and dominant trees (largest trees in the stand) are ≥ 200 years. Table 4 displays the proposed old-growth Douglas-fir forest definition for the LCNF.

Inclusion of other structural attributes in the definition are important in determining whether an old-growth stand is in early, middle, or late stages of development. When possible, management of old-growth forests in all stages of maturation is desirable because plant and animal species associated with old-growth ecosystems are likely to be linked to specific developmental stages and attributes.

Table 4. Minimum values for components included in the Douglas-fir forest type old-growth definition.

<table>
<thead>
<tr>
<th>Site</th>
<th>Cond</th>
<th>Type</th>
<th>TPH.dbh</th>
<th>Age</th>
</tr>
</thead>
<tbody>
<tr>
<td>All</td>
<td>DF</td>
<td>62&gt;34cm</td>
<td>&gt;200</td>
<td></td>
</tr>
</tbody>
</table>

*a Old-growth forest component values may need further breakdown by site condition in some forest types. Ex. Lodgepole pine (LP) types.
*b Described by dominant overstory species present.
*c Minimum number of trees per 0.4 hectare of stated dbh.
*d Minimum age of dominant live trees.

Again it is important to stress that old-growth forest ecosystems are extremely complex and thus difficult to define. This complexity
compounds the difficulties of defining old-growth forests. Nevertheless, functional definitions are necessary for determining the amount of old-growth forests that remain in an area and subsequent management practices that will ensure their preservation. Complicated definitions using a wide array of variables have been implemented in the past and newly formulated definitions continue with this trend. These definitions have provided limited success to the old-growth inventory process being initiated in central Montana as well as elsewhere. Undoubtedly the definitions can be simplified as the proposed old-growth Douglas-fir forest definition outlined in this paper suggests. Before more irreversible destruction and fragmentation occurs in these unique, complex forest ecosystems, usable definitions must be devised and agreed upon by land managers.
Chapter 2:

USEFULNESS OF THE NORTHERN GOSHAWK AS A
MANAGEMENT INDICATOR SPECIES FOR OLD-GROWTH
DOUGLAS-FIR FORESTS OF CENTRAL MONTANA

INTRODUCTION

Indicators were first used in the 1910s by plant ecologists who worked with soil productivity and agricultural crops (Patton 1987). Recently, the indicator species concept was introduced to the wildlife profession as Management Indicator Species (MIS) by the 1976 National Forest Management Act (NFMA) (Patton 1987).

The Lewis and Clark National Forest (LCNF), as well as all other National Forests, was required by the implementing regulations of NFMA to use MIS to monitor and manage old-growth forest ecosystems. The indicator species concept, in short, implies that an indicator species having restrictive habitat requirements is assumed to represent other species utilizing the same habitats. It is generally thought that by managing habitats for the health and viability of the indicator species, other species utilizing these same habitats will also be protected and maintained (Blosser 1987). An MIS is essentially a single species representative or surrogate of a community (Patton 1987, Landres et al. 1988).

The MIS approach has received considerable criticism. Landres et
al. (1988) pointed out that community responses to change can not be extrapolated from one community member to another. Few if any species groups within a community utilize habitat or respond to change so similarly that one species could be used as an indicator of others within its group (Verner 1984). Landres et al. (1988) stated that if use of the MIS concept is unavoidable, "it must be justified by research on populations of the species involved, over an extensive area and time."

The Lewis and Clark National Forest employs the Northern Goshawk (Accipiter gentilis) as a management indicator species for old-growth forests. The Northern Region, USDA Forest Service of which the LCNF is a part developed a goshawk habitat model, based on that of Hayward et al. (1983), which provided an index rating of habitat value (USDA Forest Service 1990). This model was developed for application in boreal forests of western Montana and northern Idaho. The variables considered by this model for goshawk nesting/cover habitat are: overstory tree size, canopy closure, size of nest stand, and slope. Canopy closure was judged to be the most important variable and slope the least important variable (USDA Forest Service 1990). This model has been reviewed by goshawk researchers, but has not been verified in the field.

The objectives of this study were (1) to compare old-growth Douglas-fir stands with Douglas-fir goshawk nest stands in order to evaluate the appropriateness of the goshawk as a MIS for old-growth Douglas-fir forests on the LCNF, and (2) to examine the applicability
of the nesting habitat portion of the goshawk habitat model for the LCNF.

STUDY AREA

Field work was conducted on the Jefferson Division of the Lewis and Clark National Forest in central Montana. Study sites were located in the Little Belt, Big Snowy, Castle, and Crazy Mountain ranges (Figure 3). These mountain ranges display varying topography, with elevations from 1,500 m to 2,800 m. Foothills are generally rolling grasslands with bands of Douglas-fir or ponderosa pine (See Appendix A for plant scientific names). Mid-elevation side slopes are primarily vegetated with dense stands of lodgepole pine or Douglas-fir. Grassy benches or forest/grassland mosaics are common throughout the lower and middle elevations. Higher elevations generally have steep side slopes with gentle to flat ridges. Limber pine, whitebark pine, Engelmann spruce, subalpine fir, and grassland are the dominant vegetation types of the upper elevations.

These mountain ranges are characterized by distinct fire histories that are exemplified by the fire-generated or fire-perpetuated forest types dominating the areas (Habeck 1988). Historically, lodgepole pine stands have experienced stand-replacing fires, and ponderosa pine / Douglas-fir stands along the forest-grassland ecotone have been maintained by low intensity fires. Fire disturbances may play a vital role in maintaining some old-growth forests of central Montana.
METHODS

In summer 1989, I identified 50 old-growth Douglas-fir stands in my study area. Criteria for the stand to be considered a study site were: (1) stand is dominated by Douglas-fir, (2) dominant Douglas-fir trees are large diameter [≥ 25 cm diameter-at-breast-height(dbh)], (3) no timber harvesting has occurred in the stand, and (4) stands are at
least 2 hectares (5 acres) in size. Data sources for identification of candidate old-growth Douglas-fir stands were aerial photographs, timber stand exam data, and references from Forest Service field crews and other personnel. Also in summer 1989, I surveyed 10 previously identified and 2 newly indentified northern goshawk nest stands. If a forest stand contained at least one confirmed northern goshawk nest site, the stand was classified as a goshawk nest stand. I surveyed the nest stands to confirm that their dominant live tree components were Douglas-fir and that they contained at least one old or new goshawk nest site.

In summer 1990, I randomly selected 25 old-growth Douglas-fir study stands to be sampled from the 50 which met the criteria. Time and weather permitted me to only sample 24 of these study sites. I also sampled the 12 northern goshawk nest stands. Twenty-five study stands were located in the Little Belt, five in the Big Snowy, four in the Castle, and two in the Crazy Mountains (Figure 3). Each old-growth study site and goshawk nest stand were sampled with a series of five fixed-radius plots. Plot locations were determined by a random sampling design. A line transect with five evenly spaced points bisected each sample stand as determined by use of aerial photographs. Transect length and distance between points varied with the dimensions of each stand. Stand sizes were calculated by using orthophoto quads and Digitablet 2400 by Numonics. The transect was located so that a majority of the stand fell within its reaches. The starting point of the transect was determined by choosing a random distance from 0 to 100 meters. All random distances came from a random numbers table. Once
the random starting point was determined, five evenly spaced points were
placed on the transect after the starting point. From each of the five
points, a perpendicular, random distance (-50 to 50 m) to a sample plot
center was taken. Positive and negative values corresponded to right
and left directions from the transect point. Only random numbers which
selected plots within the study stands were used. The transect approach
attempted to reduce the likelihood of concentrating the sample plots in
specific areas of the stands. Therefore, it allowed me the opportunity
to sample portions of the entire stand.

The stands were sampled using circular plots with radii of 11.3 m
(area = 0.04 ha) and 4.6 m (area = 0.007 ha). Primary stand
characteristics were measured on the 0.04 ha plots and secondary stand
characteristics were measured on the 0.007 ha plots. Three 0.007 ha
plots were nested concentrically inside the first, third and fifth plots
of the 0.04 ha plots (Figure 4).
Physiographic data was taken at plot center of each 0.04 ha plot (elevation, slope, aspect, and habitat type (Pfister et al. 1977)).

Trees, snags, and downed logs were considered primary stand components. Trees (>20 cm dbh), snags (> 10 cm dbh), and downed logs (>10 cm bottom diameter) were measured and characterized on the 0.04 ha plot. Species (if possible), height and dbh were recorded for trees and snags. Heights were estimated after a few heights were measured at each plot. I recorded percent canopy cover and descriptions of snags and
logs such as snag condition (after Cline et al. 1980, see Appendix B), and log condition (after Thomas et al. 1979, see Appendix C). The two largest (>20 cm dbh) Douglas-fir trees in each of the 0.04 ha plots were cored and aged. If two large Douglas-fir trees were not located in the plot, large trees (>20 cm dbh) closest to the plot were used. Volume of downed logs (>10 cm bottom diameter) in the 0.04 ha plots was estimated by measuring log length and the log's top and bottom diameters. Volume was calculated with the frustrum of a cone formula (J. Brown pers. comm.).

Small trees, seedlings, shrubs, tree canopy, and ground cover types were considered secondary old-growth components. Trees (0-20 cm dbh), seedlings (>50 cm tall), and shrubs (>50 cm tall) were tallied by species on the 0.007 ha plots.

Tree canopy, seedling, shrub, and ground cover were calculated, on the first, third, and fifth 0.04 ha plots, using a method developed by Hejl (1989). Seven points, placed at 0.0, 3.9, 6.0, 7.5, 8.7, 9.8, and 10.8 m intervals, were located in each cardinal direction (N, E, S, and W) from plot center. The type of cover and species were noted after sighting upward and downward from each point. Percent cover was calculated by multiplying the number of points blanketed by each cover type by four. Ground cover types were litter, rock, soil, downed wood, grass, forb, water, and other.

T tests were used to test the hypothesis that mean values of the measured variables that were derived from the old-growth stands were equal to the mean values from the goshawk nest stands.
Mean values of overstory tree size, canopy closure, size of nest stand, and slope from each study stand were applied to the nesting/cover portion of the goshawk habitat model. Subsequently a single index value was generated for each stand. Index values were calculated as follows:

\[
\text{nesting/cover value} = \left[ \frac{(2 \times V(cc)) + V(dbh) + V(acres) + V(slope))}{5} \right]
\]

where

- \( V(cc) \) = percent canopy closure
- \( V(dbh) \) = diameter of overstory trees
- \( V(acres) \) = nest stand acres
- \( V(slope) \) = average slope of stand

\[\]

\( V(cc) \): canopy closure

<table>
<thead>
<tr>
<th>% Closure</th>
<th>0 - 39</th>
<th>40 - 70</th>
<th>&gt; 70</th>
</tr>
</thead>
<tbody>
<tr>
<td>Value</td>
<td>0.0</td>
<td>0.4</td>
<td>1.0</td>
</tr>
</tbody>
</table>

\[\]

\( V(dbh) \): overstory tree size

<table>
<thead>
<tr>
<th>Average DBH</th>
<th>5 - 8</th>
<th>9 - 14</th>
<th>15 - 20</th>
<th>&gt; 20</th>
</tr>
</thead>
<tbody>
<tr>
<td>Value</td>
<td>0.0</td>
<td>0.4</td>
<td>0.8</td>
<td>1.0</td>
</tr>
</tbody>
</table>

\[\]

\( V(acres) \): size of nest stand

<table>
<thead>
<tr>
<th>Acres</th>
<th>21 - 50</th>
<th>51 - 100</th>
<th>101 - 150</th>
<th>151 - 200</th>
<th>201 - 250</th>
<th>&gt; 250</th>
</tr>
</thead>
<tbody>
<tr>
<td>Value</td>
<td>0.1</td>
<td>0.3</td>
<td>0.6</td>
<td>0.8</td>
<td>0.9</td>
<td>1.0</td>
</tr>
</tbody>
</table>

\[\]

\( V(slope) \): average slope within nest stand

<table>
<thead>
<tr>
<th>Percent Slope</th>
<th>&lt; 20</th>
<th>21 - 30</th>
<th>31 - 40</th>
<th>41 - 50</th>
<th>51 - 60</th>
<th>&gt; 60</th>
</tr>
</thead>
<tbody>
<tr>
<td>Value</td>
<td>1.0</td>
<td>0.9</td>
<td>0.7</td>
<td>0.6</td>
<td>0.1</td>
<td>0.0</td>
</tr>
</tbody>
</table>

Possible index values range between 0.0 and 1.0 where 1.0 theoretically represents optimum goshawk nest habitat.

A t test was used to test the hypothesis that mean index values for the two stand types were equal.
RESULTS

Comparison of Old-Growth Stands and Goshawk Nest Stands

Physiographic Data

Twenty-one previously verified old-growth Douglas-fir stands and twelve Douglas-fir goshawk nest stands encompassed essentially the same range of elevations; elevations of old-growth stands averaged 1,991 m and nest stands 1,810 m. Stand slopes averaged 32% for old growth and 28% for goshawk nest stands. Recorded habitat types for both stand types varied widely, covering the range within the *Psuedotsuga menzeisii* series found in central Montana but included other climax series habitat types as well. Stand orientations presented a marked contrast between old-growth Douglas-fir and Douglas-fir goshawk nest stands. All sample nest stands were on northerly aspects, whereas old growth stands were equally distributed among the primary compass directions. Appendix E presents summary data, using mean values, from each old-growth stand and goshawk nest stand.

Primary Stand Components

Live trees. A total of 1,395 live trees (>20 cm dbh) were sampled on the old-growth study sites and 1,121 live trees were sampled on goshawk nest sites. Eighty-seven percent of the measured trees were Douglas-fir
on the old-growth stands and 82% were Douglas-fir on the nest stands. Of the measured live trees, 28% were $\geq 43$ cm dbh on the old-growth stands, whereas only 10% were $\geq 43$ cm dbh on the goshawk nest stands (Figure 5).

Mean live tree dbh was 36 cm for old-growth stands and 31 cm dbh for nest stands (Table 5). The t-test determined that these mean live tree dbhs were significantly different at the 1% level. Mean live tree ages were also calculated for each study stand. Using mean values from each stand, overall mean live tree age was calculated at 268 years for old-growth stands and 203 years for goshawk nest stands (Table 5). Mean live tree ages were significantly different at the 1% significance level. Overall live tree density was 130 per $0.4$ ha for old growth and 190 per $0.4$ ha for goshawk nest stands (Table 5). Difference in tree density between stand types was statistically significant at the 1% level.
Figure 5. Diameter (dbh) distribution (% frequency by stand) of live trees.
Table 5. Comparison of primary and secondary components of old-growth stands and goshawk nest stands.

<table>
<thead>
<tr>
<th></th>
<th>95% Confidence Intervals</th>
<th>N</th>
<th>p-values</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Live trees</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>dbh</td>
<td>21: 36.0 ± 1.5</td>
<td>31.0 ± 0.5</td>
<td>12: 0.000</td>
</tr>
<tr>
<td>age</td>
<td>21: 268.0 ± 36.3</td>
<td>203.0 ± 16.0</td>
<td>12: 0.010</td>
</tr>
<tr>
<td>no./0.4 ha</td>
<td>21: 130.0 ± 13.5</td>
<td>190.0 ± 10.0</td>
<td>12: 0.001</td>
</tr>
<tr>
<td><strong>Snags</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>dbh</td>
<td>21: 28.0 ± 3.6</td>
<td>18.0 ± 0.8</td>
<td>12: 0.000</td>
</tr>
<tr>
<td>no./0.4 ha</td>
<td>21: 45.0 ± 10.0</td>
<td>65.0 ± 5.0</td>
<td>12: 0.003</td>
</tr>
<tr>
<td><strong>Downed logs</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>no./0.4 ha</td>
<td>21: 195.0 ± 44.0</td>
<td>250.0 ± 20.0</td>
<td>12: 0.066</td>
</tr>
<tr>
<td>vol/log</td>
<td>21: 0.8 ± 0.15</td>
<td>0.4 ± 0.03</td>
<td>12: 0.000</td>
</tr>
<tr>
<td>vol/0.4 ha</td>
<td>21: 100.0 ± 28.0</td>
<td>65.0 ± 21.0</td>
<td>12: 0.038</td>
</tr>
<tr>
<td><strong>Trees</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>canopy cover</td>
<td>21: 55.0 ± 4.8</td>
<td>72.0 ± 3.0</td>
<td>12: 0.000</td>
</tr>
<tr>
<td>% cover</td>
<td>21: 16.0 ± 5.4</td>
<td>21.0 ± 5.0</td>
<td>12: 0.333</td>
</tr>
<tr>
<td>no./0.4 ha</td>
<td>21: 715.0 ± 427.6</td>
<td>1,361.0 ± 330.0</td>
<td>12: 0.154</td>
</tr>
<tr>
<td><strong>Small trees</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>no./0.4 ha</td>
<td>21: 206.0 ± 174.6</td>
<td>96.0 ± 27.5</td>
<td>12: 0.207</td>
</tr>
<tr>
<td><strong>Seedlings</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>no./0.4 ha</td>
<td>21: 413.0 ± 244.8</td>
<td>165.0 ± 68.8</td>
<td>12: 0.087</td>
</tr>
</tbody>
</table>

\[a\] All densities were in numbers per 0.4 hectare (1.0 acre).

**Snags.** A total of 481 coniferous snags (>10 cm dbh) were sampled on the old-growth study sites and 392 on the goshawk nest sites. Of the measured snags, 48% were > 23 cm dbh on the old growth sites while only 17% were > 23 cm dbh on the goshawk nest sites (Figure 6).

Mean snag dbh was 28 cm on old-growth sites and 18 cm dbh on nest sites (Table 5). Difference in snag dbh between the two stand types was statistically significant at the 1% level. Using mean values by stand, old-growth forest stands averaged 40 snags per 0.4 ha and goshawk nest stands averaged 65 snags per 0.4 ha (Table 5). These values differed significantly at the 1% significance level.
Snag decomposition classes used were described by Cline et al. (1980) (Appendix B). Of snags recorded on each old-growth study site, an average 25% were assigned to decomposition class 1, 24% to class 2, 23% to class 3, 21% to class 4, and 7% to class 5. On each goshawk nest stands, an average of 37% of the recorded snags were assigned to decomposition class 1, 23% to class 2, 18% to class 3, 19% to class 4, and 2% to class 5. No distinct differences were seen in the distribution of the snags, from the two stand types, in the decomposition classes.

Figure 6. Diameter (dbh) distribution (% frequency by stand) of snags.
Downed logs. A total of 2,167 downed logs were measured on the old-growth study stands and 1,490 on the goshawk nest stands. Of the measured logs, 45% were ≥ 23 cm bottom diameter on the old-growth sites while only 25% were ≥ 23 cm bottom diameter on the goshawk nest sites (Figure 7).

Downed log density averaged 195 per 0.4 ha on old-growth stands and 250 per 0.4 ha on goshawk nest stands (Table 5). Differences between these mean log density values were nearly significant at the 5% level. Mean volume per downed log was 0.8 m³ per log on old-growth sites and 0.4 m³ per log on nest sites (Table 5). Difference in volume per log between the stand types was significant at the 1% significance level. Total log volume averaged 100.0 m³ per 0.4 ha on the old-growth stands and 65.0 m³ per 0.4 ha on the goshawk nest stands (Table 5). The difference was significant at the 5% level.

Downed log decomposition classes used were described by Thomas et al. (1979) (See Appendix C). Of downed logs measured on each old-growth site, an average 3% were assigned to class 1, 13% to class 2, 40% to class 3, 25% to class 4, and 17% to class 5. On each goshawk nest stand, an average of 3% of the recorded downed logs were assigned to class 1, 13% to class 2, 46% to class 3, 25% to class 4, and 13% to class 5. No significant difference was seen in the distribution of logs, from the two stand types, in the downed log decomposition classes.
Figure 7. Bottom diameter distribution (% frequency by stand) of downed logs.

**Secondary Stand Components**

Percent canopy cover had a mean value of 55% for old-growth sites and 72% for nest sites (Table 5). This difference was significant at the 1% significance level. Neither shrub cover, shrub density, small tree density, or seedling density differed between the two types of stands (Table 5).
A total 1,532 ground cover recordings were taken on the old-growth study sites and 735 recordings were taken on the goshawk nest sites. Of these recordings, 502 (34%) were recorded as litter, 436 (29%) as forb, 233 (15%) as downed wood, 216 (14%) as grass, 110 (7%) as other (moss, lichen, and seedlings), 27 (2%) as rock, and 8 (1%) as soil on the old growth sites. On the goshawk nest stands, 342 (47%) recordings were litter, 154 (21%) forb, 135 (18%) downed wood, 49 (7%) grass, 46 (6%) other (moss, lichen, and seedlings), 6 (1%) rock, and 3 (0.04%) soil. No significant difference was seen between these distributions.

Application of the Goshawk Habitat Model

Index values for old-growth study stands ranged from 0.26 to 0.76, with a mean value of 0.46. Index values for goshawk nest stands ranged from 0.38 to 0.70, with 0.58 as the mean value. Mean index values for the two stand types differed significantly ($p = 0.009$) (Table 6). This difference suggested that the goshawk habitat model was successful in rating the nest stands higher than the old-growth stands.
Table 6. Mean index values, using the goshawk habitat model, generated from old-growth stands and goshawk nest stands.

<table>
<thead>
<tr>
<th>Stand Type</th>
<th>N</th>
<th>$\bar{X}$</th>
<th>95% CI</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Old Growth</td>
<td>21</td>
<td>0.47</td>
<td>0.47 $\pm$ 0.05</td>
<td>0.009</td>
</tr>
<tr>
<td>Nest Stands</td>
<td>12</td>
<td>0.58</td>
<td>0.58 $\pm$ 0.07</td>
<td></td>
</tr>
</tbody>
</table>

However, a critical problem with the model was that many stands within each type produced the same index value even though the forest stands were notably structurally different. For example, old-growth stands BRPK, INBB, SDPT, and TRCB produced the same 0.44 index value (Table 7). Stands from each group had replicated index values (Table 7).
Table 7. Index values, using the goshawk habitat model, for the old-growth stands and goshawk nest stands.

<table>
<thead>
<tr>
<th>STD ID</th>
<th>%CC</th>
<th>Tree dbh</th>
<th>acres</th>
<th>slope</th>
<th>Index Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Old Growth</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BRPK</td>
<td>47</td>
<td>13</td>
<td>25</td>
<td>23</td>
<td>0.44</td>
</tr>
<tr>
<td>CEMN</td>
<td>77</td>
<td>13</td>
<td>22</td>
<td>7</td>
<td>0.70</td>
</tr>
<tr>
<td>CYMN</td>
<td>43</td>
<td>14</td>
<td>42</td>
<td>40</td>
<td>0.40</td>
</tr>
<tr>
<td>GNMN</td>
<td>55</td>
<td>16</td>
<td>26</td>
<td>30</td>
<td>0.52</td>
</tr>
<tr>
<td>INBA</td>
<td>64</td>
<td>15</td>
<td>58</td>
<td>13</td>
<td>0.58</td>
</tr>
<tr>
<td>INBB</td>
<td>48</td>
<td>13</td>
<td>32</td>
<td>21</td>
<td>0.44</td>
</tr>
<tr>
<td>KSGH</td>
<td>52</td>
<td>13</td>
<td>7</td>
<td>22</td>
<td>0.42</td>
</tr>
<tr>
<td>KYCK</td>
<td>63</td>
<td>14</td>
<td>42</td>
<td>35</td>
<td>0.40</td>
</tr>
<tr>
<td>LGCK</td>
<td>65</td>
<td>13</td>
<td>234</td>
<td>50</td>
<td>0.52</td>
</tr>
<tr>
<td>LYBY</td>
<td>55</td>
<td>16</td>
<td>26</td>
<td>27</td>
<td>0.52</td>
</tr>
<tr>
<td>MRGA</td>
<td>41</td>
<td>13</td>
<td>11</td>
<td>28</td>
<td>0.42</td>
</tr>
<tr>
<td>MRGC</td>
<td>43</td>
<td>13</td>
<td>27</td>
<td>37</td>
<td>0.40</td>
</tr>
<tr>
<td>MTPA</td>
<td>43</td>
<td>16</td>
<td>52</td>
<td>40</td>
<td>0.52</td>
</tr>
<tr>
<td>NLCK</td>
<td>60</td>
<td>13</td>
<td>11</td>
<td>41</td>
<td>0.32</td>
</tr>
<tr>
<td>RKRE</td>
<td>49</td>
<td>15</td>
<td>47</td>
<td>22</td>
<td>0.52</td>
</tr>
<tr>
<td>SDHE</td>
<td>45</td>
<td>14</td>
<td>6</td>
<td>53</td>
<td>0.26</td>
</tr>
<tr>
<td>SDPT</td>
<td>56</td>
<td>15</td>
<td>35</td>
<td>26</td>
<td>0.44</td>
</tr>
<tr>
<td>TRCA</td>
<td>49</td>
<td>16</td>
<td>21</td>
<td>41</td>
<td>0.44</td>
</tr>
<tr>
<td>TRCB</td>
<td>55</td>
<td>16</td>
<td>24</td>
<td>65</td>
<td>0.34</td>
</tr>
<tr>
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<td>61</td>
<td>14</td>
<td>68</td>
<td>41</td>
<td>0.40</td>
</tr>
<tr>
<td>WLCB</td>
<td>73</td>
<td>15</td>
<td>30</td>
<td>28</td>
<td>0.76</td>
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<td><strong>Nest Stands</strong></td>
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<td></td>
<td></td>
</tr>
<tr>
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<td>28</td>
<td>19</td>
<td>0.70</td>
</tr>
<tr>
<td>CNCK</td>
<td>76</td>
<td>12</td>
<td>16</td>
<td>31</td>
<td>0.62</td>
</tr>
<tr>
<td>DUGH</td>
<td>71</td>
<td>10</td>
<td>13</td>
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<td>0.58</td>
</tr>
<tr>
<td>ETRK</td>
<td>64</td>
<td>13</td>
<td>3</td>
<td>13</td>
<td>0.44</td>
</tr>
<tr>
<td>FGSF</td>
<td>72</td>
<td>10</td>
<td>66</td>
<td>48</td>
<td>0.64</td>
</tr>
<tr>
<td>LECK</td>
<td>53</td>
<td>14</td>
<td>6</td>
<td>37</td>
<td>0.38</td>
</tr>
<tr>
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<td>12</td>
<td>45</td>
<td>9</td>
<td>0.46</td>
</tr>
<tr>
<td>NLCB</td>
<td>73</td>
<td>12</td>
<td>13</td>
<td>18</td>
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</tr>
<tr>
<td>PEGH</td>
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<td>34</td>
<td>27</td>
<td>0.68</td>
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<tr>
<td>TDGH</td>
<td>81</td>
<td>13</td>
<td>7</td>
<td>25</td>
<td>0.66</td>
</tr>
<tr>
<td>WBCK</td>
<td>68</td>
<td>14</td>
<td>36</td>
<td>26</td>
<td>0.44</td>
</tr>
<tr>
<td>WLCB</td>
<td>77</td>
<td>12</td>
<td>7</td>
<td>24</td>
<td>0.66</td>
</tr>
</tbody>
</table>

\(a\) Tree dbh was expressed in inches.
\(b\) Slope was expressed in percent.
DISCUSSION AND MANAGEMENT IMPLICATIONS

Addressing the applicability of the goshawk habitat model to the LCNF is difficult. Obviously more field testing is necessary in order to refine the model so that it includes the most meaningful variables and assigns accurate, interpretable index values. Researchers should apply the model to established goshawk nest stands to aid in refining the model and to create a ranking system where certain ranges of index values receive, for example, poor, moderate, or good rankings. As it stands, there is no way to differentiate between potentially good and poor goshawk nest stands. Also the model must be adjusted for geographic areas in order to compensate for the notable differences between "eastside" and "westside" forests. If wildlife managers desire to manage habitat for the northern goshawk, they must identify the hawk's needs and requirements, and prescribe management techniques accordingly.

On the other hand, the data provided strong evidence that old-growth Douglas-fir stands and Douglas-fir goshawk nest stands were structurally different. First, stand orientation showed a marked contrast between the two forest stand types. Goshawk nest stands were all located on north aspects whereas old-growth stands were found on all aspects. If land managers were only to manage north facing stands for the goshawk, as the data and MIS concept suggest, plant and animal species that occupy stands on other aspects may be neglected or mismanaged. Obviously old-growth stands are located on all aspects and should be managed accordingly.
Another notable difference concerned live trees. Old-growth forest stands supported older, larger dbh live trees with open canopies while goshawk nest stands had younger, smaller dbh live trees with dense canopies.

Snag characteristics were also dissimilar between the two stand types. Old-growth stands supported fewer and larger snags while nest stands had smaller dbh snags but more snags per hectare. Past research reinforces the fact that large snags can potentially provide for a wider variety of animal species, especially birds (Thomas et al. 1979, Bull 1987). Sole management of goshawk habitat may have diminishing effects on animal species dependant on snags.

Data related to downed logs also supported evidence of differences between old-growth stands and goshawk nest stands. Old-growth stands contained larger logs and more total downed log volume per hectare. Nest stands had smaller logs and more logs per hectare. Like larger snags, larger downed logs may potentially support a greater diversity of plant and animal species (Franklin et al. 1981).

In short, old-growth Douglas-fir stands are significantly different than Douglas-fir goshawk nest stands when comparing characteristics normally associated with old-growth stands as well as other characteristics. This information should be recognized and contemplated when devising management plans based on MISs for special interest ecosystems such as old-growth forests which are being depleted on a daily basis.

Clearly the northern goshawk is not a good choice as a management indicator species for old-growth Douglas-fir forests on the Lewis and
Clark National Forest. Since Douglas-fir forests represent a substantial amount of the LCNF's timber base, another old-growth MIS could be implemented or other old-growth management techniques could be employed. In any case, as Landres et al. (1988) stated, if use of MIS is unavoidable, it must be backed by extensive research.
LITERATURE CITED


### APPENDIX A

**PLANT SCIENTIFIC NAMES (Hitchcock and Cronquist 1973)**

<table>
<thead>
<tr>
<th>Common Name</th>
<th>Scientific Name</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Tree Species</strong></td>
<td></td>
</tr>
<tr>
<td>Douglas-fir</td>
<td>Pseudotsuga menziesii</td>
</tr>
<tr>
<td>lodgepole pine</td>
<td>Pinus contorta</td>
</tr>
<tr>
<td>Engelmann spruce</td>
<td>Picea engelmannii</td>
</tr>
<tr>
<td>subalpine fir</td>
<td>Abies lasiocarpa</td>
</tr>
<tr>
<td>ponderosa pine</td>
<td>Pinus ponderosa</td>
</tr>
<tr>
<td>limber pine</td>
<td>Pinus flexilis</td>
</tr>
<tr>
<td>western redcedar</td>
<td>Thuja plicata</td>
</tr>
<tr>
<td>Rocky mountain maple</td>
<td>Acer glabrum</td>
</tr>
<tr>
<td><strong>Shrub Species</strong></td>
<td></td>
</tr>
<tr>
<td>common snowberry</td>
<td>Symphoricarpos albus</td>
</tr>
<tr>
<td>common juniper</td>
<td>Juniperus communis</td>
</tr>
<tr>
<td>mountain gooseberry</td>
<td>Ribes montigenum</td>
</tr>
<tr>
<td>white spiraea</td>
<td>Spiraea betuliolia</td>
</tr>
<tr>
<td>buffaloberry</td>
<td>Shepherdia canadensis</td>
</tr>
<tr>
<td>Wood's rose</td>
<td>Rosa woodsii var. woodsii</td>
</tr>
<tr>
<td>blue huckleberry</td>
<td>Vaccinium globulare</td>
</tr>
<tr>
<td>mountain snowberry</td>
<td>Symphoricarpos oreophilis</td>
</tr>
<tr>
<td>chokecherry</td>
<td>Prunus virginiana</td>
</tr>
<tr>
<td>ninebark</td>
<td>Physocarpus malvaceus</td>
</tr>
<tr>
<td>elderberry</td>
<td>Sambucus racemosa</td>
</tr>
<tr>
<td><strong>Other Recorded Species</strong></td>
<td></td>
</tr>
<tr>
<td>Oregon grape</td>
<td>Berberis repens</td>
</tr>
<tr>
<td>kinnikinnick</td>
<td>Arctostaphylos uva-ursi</td>
</tr>
<tr>
<td>red raspberry</td>
<td>Rubus idaeus</td>
</tr>
<tr>
<td>twinflower</td>
<td>Linnnea borealis</td>
</tr>
<tr>
<td>dogwood</td>
<td>Cornus (spp.)</td>
</tr>
</tbody>
</table>
APPENDIX B

Snag Condition: Physical characteristics and stages of deterioration (Cline et al. 1980).

<table>
<thead>
<tr>
<th>Limbs and branches</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>All present</td>
<td>Few limits, no fine branches</td>
<td>Limb stubs only</td>
<td>Few or no stubs</td>
<td>None</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Top Diameter, broken</th>
<th>Painted</th>
<th>Broken</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increasing at decreasing rate</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Top Height</th>
<th>Decreasing at decreasing rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Variable</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Bark remaining %</th>
<th>100</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt;20</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sapwood presence</th>
<th>Insect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sloughing</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sapwood condition</th>
<th>Sound, incipient decay, hard, original color</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fibrous, soft to reddish brown</td>
<td></td>
</tr>
<tr>
<td>Cubical, soft, reddish to dark brown</td>
<td></td>
</tr>
<tr>
<td>None</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Heartwood condition</th>
<th>Sound, incipient decay at upper hole, hard, light to reddish brown</th>
</tr>
</thead>
<tbody>
<tr>
<td>Incipient decay throughout upper hole, light to reddish brown</td>
<td></td>
</tr>
<tr>
<td>Advanced decay at base, reddish brown</td>
<td></td>
</tr>
<tr>
<td>Sloughing, cubical, soft, brown, dark reddish brown</td>
<td></td>
</tr>
<tr>
<td>None</td>
<td></td>
</tr>
</tbody>
</table>

| Estimated age at which snags reach a deterioration stage: |
|---------------|-----------------|
| 9-18 cm dbh* | 0-4 | 5-8 | 9-16 | >17 | Fallen |
| 19-47 cm dbh | 0-3 | 6-13 | 14-29 | 30-60 | >60 |
| >47 cm dbh | 0-6 | 7-18 | 19-50 | 51-125 | >125 |

* snags reach a deterioration stage. 

49
APPENDIX C

Log Condition: Physical characteristics and stages of deterioration (Thomas et al. 1979).

<table>
<thead>
<tr>
<th>Log characteristics</th>
<th>Log decomposition class</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Bark</td>
<td>intact</td>
</tr>
<tr>
<td>Twigs &lt; 3 cm (1.18 in)</td>
<td>present</td>
</tr>
<tr>
<td>Texture</td>
<td>intact</td>
</tr>
<tr>
<td>Shape</td>
<td>round</td>
</tr>
<tr>
<td>Color of wood</td>
<td>original color</td>
</tr>
<tr>
<td>Portion of log on ground</td>
<td>log elevated on support points</td>
</tr>
</tbody>
</table>

Log class 1 | Log class 2 | Log class 3 | Log class 4 | Log class 5

50
Primary and secondary old-growth stand components from three old-growth stands not included in analysis.

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>X</th>
<th>95% CI</th>
<th>Range</th>
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<tbody>
<tr>
<td>Live trees</td>
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<td></td>
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<td></td>
</tr>
<tr>
<td>dbh</td>
<td>3</td>
<td>38.0</td>
<td>38.0 ± 1.5</td>
<td>8.0-24.0</td>
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<tr>
<td>height</td>
<td>3</td>
<td>17.0</td>
<td>17.0 ± 0.6</td>
<td>8.0-26.0</td>
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<tr>
<td>age</td>
<td>3</td>
<td>178.0</td>
<td>178.0 ± 23.3</td>
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<tr>
<td>no./0.4 ha</td>
<td>3</td>
<td>105.0</td>
<td>105.0 ± 26.5</td>
<td>30.0-220.0</td>
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<td>Snags</td>
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<tr>
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<td>3</td>
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<td>110.0 ± 109.0</td>
<td>55.0-138.0</td>
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<tr>
<td>Seedlings</td>
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<td>3</td>
<td>330.0</td>
<td>330.0 + 630.0</td>
<td>110.0-605.0</td>
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a All diameters were measured in centimeters.
b All heights were measured in meters.
c Age was in years.
d All densities were in numbers per 0.4 ha (1.0 acre).
e Covers were expressed in percentages.
f Volume was expressed in square meters per 0.4 ha.
APPENDIX E

Summary data from each old-growth stand and goshawk nest stand.

Old-Growth Stands:

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<tr>
<th>STAND ID</th>
<th>LOCATION</th>
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<td>BEAR PARK</td>
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<td>TREE DBH</td>
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<td>14 M</td>
<td>14 M</td>
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<td>9%</td>
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<td>39%</td>
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<td>W</td>
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<td>182</td>
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**LYBY**
- **Elevation**: 2,064 m
- **Tree Height**: 15 m
- **SNAG Height**: 8 m
- **Vol/Log (m³)**: 1.1
- **Shrub Density**: 69/0.4 HA

**Legal Location**: T10N, R11E, SEC 7, NE 1/4
- **Slope**: 28%
- **Hectares**: 160/0.4 HA

**LYBY**
- **Elevation**: 1,843 m
- **Tree Height**: 17 m
- **SNAG Height**: 11 m
- **Vol/Log (m³)**: 0.7
- **Shrub Density**: 1,746/0.4 HA

**Legal Location**: T11N, R7E, SEC 8, SW 1/4
- **Slope**: 29%
- **Hectares**: 135/0.4 HA

**LYBY**
- **Elevation**: 1,773 m
- **Tree Height**: 19 m
- **SNAG Height**: 9 m
- **Vol/Log (m³)**: 0.9
- **Shrub Density**: 894/0.4 HA

**Legal Location**: T11N, R7E, SEC 19, SE 1/4
- **Slope**: 36%
- **Hectares**: 85/0.4 HA

**LYBY**
- **Elevation**: 2,064 m
- **Tree Height**: 15 m
- **SNAG Height**: 8 m
- **Vol/Log (m³)**: 1.1
- **Shrub Density**: 69/0.4 HA

**Legal Location**: T10N, R11E, SEC 7, NE 1/4
- **Slope**: 28%
- **Hectares**: 160/0.4 HA
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<td>ELEVATION</td>
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<td>STUD HORSE</td>
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### Goshawk Nest Stands:

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