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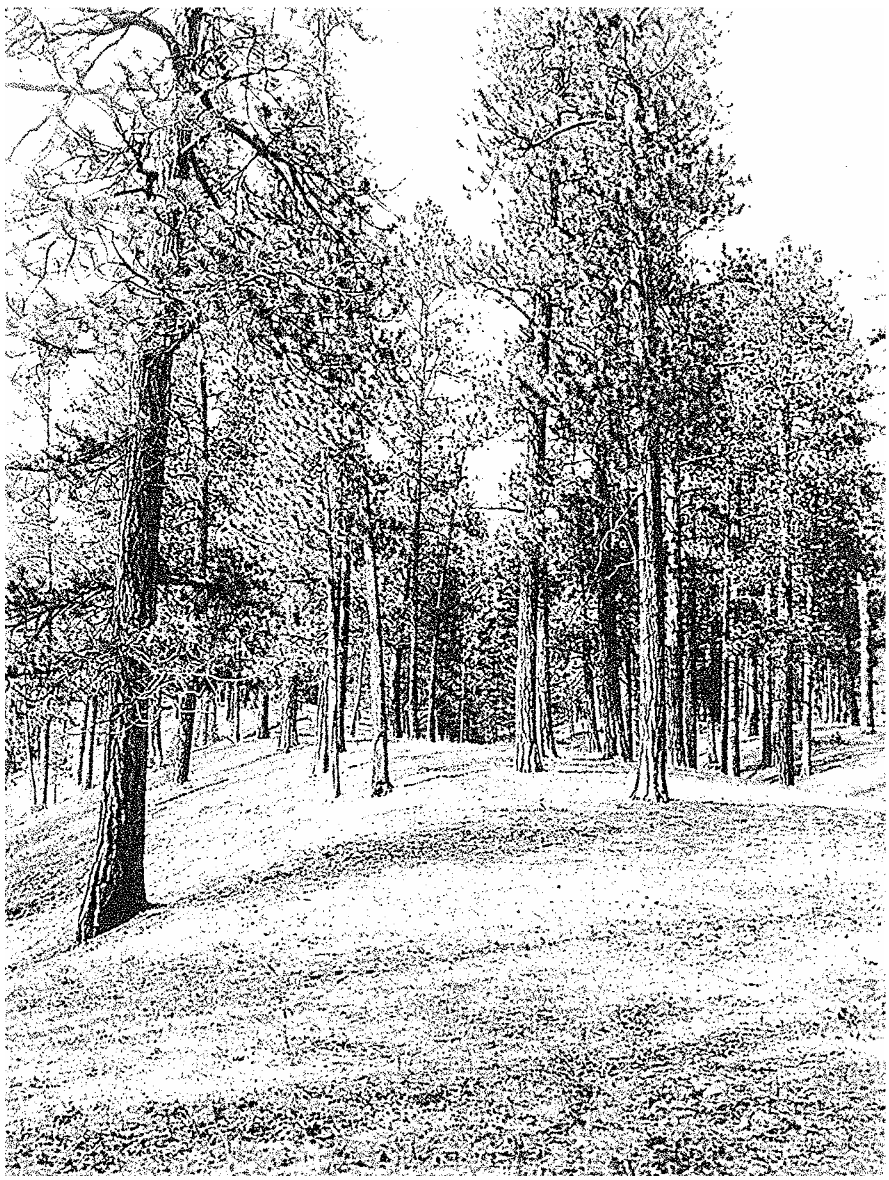
Forest Health Assessment
for the
Okanogan and Wenatchee National Forests



Forest Health Assessment:

Okanogan and Wenatchee National Forests

2 August 2004

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We may need to rethink what ecosystems in the interior West will look like. Reducing fuels to pre-European settlement levels may be a misplaced goal. We would be trying to restore against a strong climate signal, like trying to push the tide back out into the ocean. We have three options. We can try to enforce the ecological status quo, which will be increasingly difficult. We can sit back and let change happen. Or, we can manage for change.

Ron Neilson
Pacific Northwest Research Station
Science Update, 2004

Table of Contents

Forest Health Assessment: 2
Okanogan and Wenatchee National Forests 2
Table of Contents i
List of Figures iii
List of Tables iv
Overview 5
I. Introduction 5
Previous Assessments 6
Current Assessment 7
II. Current Situation 9
Current Management 9
III. Procedures and Methods 15
Methods Used 15
Forest Vegetation 15
Insects 15
Forest Diseases 16
Fire and Fuels 17
Wildlife Habitats 18
Focal Species Selection Criteria 19
Primary Criteria 19
Other Considerations 19
IV. Ecological Processes 22
Natural Variability and Ecosystem Restoration 22
Disturbance Regimes and Disturbance Processes 24
Insect and Disease Processes 24
Bark Beetles 25
Mountain Pine Beetle 25
Spruce Beetle 25
Douglas-Fir Beetle 25
Fir Engraver 26
Defoliators 26
Western Spruce Budworm 27
Douglas-Fir Tussock Moth 27
Dwarf Mistletoes 27
Other Tree Diseases 28
Fire Regimes and Fire Processes 28
Wildlife Ecology and Processes 31
Flammulated Owl and White-Headed Woodpecker—Old Growth Ponderosa Pine Forest Habitats 31
Northern Spotted Owl—Mixed Conifer Late-Successional Forest Habitats 32
Canada Lynx—Subalpine Forest Habitats 33

V. Findings ... 35
Vegetation ... 35
North Zone ... 36
Central Zone ... 38
South Zone ... 40
Insects and Diseases ... 41
North Zone ... 44
Central Zone ... 47
South Zone ... 49
Fire ... 50
Forest-Wide ... 50
North Zone ... 51
Central Zone ... 56
Wildlife ... 65
Flammulated Owl and White-Headed Woodpecker ... 65
Northern Spotted Owl ... 66
Canada Lynx ... 67
VI. Conclusions ... 69
Literature Cited ... 72
Appendix A: Forest Health Assessment Vegetation Layer ... 85
Forest Types ... 85
Warm Dry/Hot Dry Forest ... 85
Mesic Forest ... 86
Wenatchee (Neiman) GIS Coverages ... 86
Okanogan (USU) GIS Coverages ... 86
Moist Forest ... 86
Wenatchee (Neiman) GIS Coverages ... 86
Okanogan (USU) GIS Coverages ... 87
Cold Dry Forest ... 87
Wenatchee (Neiman) GIS Coverages ... 87
Okanogan (USU) GIS Coverages ... 87
Appendix B: Criteria to Evaluate Effects on Wildlife Habitat ... 88
Literature Cited ... 92
Appendix C: The Scale of the Restoration Problem ... 94
Annual Treatment to Restore Pre-Settlement Stand Densities and Structures ... 94
Analysis and Discussion ... 94
Conclusions ... 97
Literature Cited ... 98
Appendix D: Time between Project Inception and Completion ... 99
Appendix E: Rationale for the Selection of Focal Wildlife Species Used in the Forest Health Assessment ... 102
Dry forest ... 102
Late-successional Mixed Conifer Forest (Mesic and Moist Forests) ... 102
Cold Dry Forest ... 102
Literature Cited ... 103

List of Figures

Figure A. Total acres mechanically treated by non-commercial thinning (Pct+Rel) and timber harvest between 1993 and 2003, Okanogan and Wenatchee National Forests................10
Figure B. Acres treated with prescribed fire between 1993 and 2003, Okanogan and Wenatchee National Forests...11
Figure C. Distribution of acres among forest types, Okanogan and Wenatchee National Forests12
Figure D. Net acres burned, by forest type, between 1990 and 2003 on the Okanogan and Wenatchee National Forests. Only fires larger than 100 acres are included. 13
Figure E. Modeled natural range of variation for the north central Cascades of Washington (summarized from Agee 2003) 23
Figure F. Forest vegetation types, North Zone...37
Figure G. Forest vegetation types, Central Zone 39
Figure H. Forest vegetation types, South Zone 41
Figure I. Tree mortality from bark beetles and defoliator insects, 1980-2002, forest-wide (Okanogan and Wenatchee National Forests) 42
Figure J. Extensive bark beetle-caused mortality by forest type, 1980-2002.......................43
Figure K. Acres of trees killed by bark beetles, 2000-2002, North Zone............................45
Figure L. Bark beetle activity, 2000-2002, North Zone 46
Figure M. Bark beetle activity, 2000-2002, Central Zone 48
Figure N. Insect activity, 2000-2002, South Zone..49
Figure O. Crown and surface fire potential, North Zone 52
Figure P. Acres at risk of crown and surface fire, by vegetation type and structure, North Zone 53
Figure Q-1. Fire start density map displays where the most fire starts have occurred, per square mile, over the last thirty years. Data set from 1970-1999, North Zone, (USDA 2003). 54
Figure Q-2. Fire start density map displays where the most fire starts have occurred, per square mile, over the last thirty years. Data set from 1970-1999, North Zone, (USDA 2003). 55
Figure R. Crown and surface fire potential, Central Zone 57
Figure S. Acres at risk of crown and surface fire, by vegetation type and structure, Central Zone 58
Figure T-1. Fire start density map displays where the most fire starts have occurred, per square mile, over the last thirty years. Data set from 1970-1999, Central Zone (USDA 2003)......59
Figure T-2. Fire start density map displays where the most fire starts have occurred, per square mile, over the last thirty years. Data set from 1970-1999, Central Zone, (USDA 2003).....60
South Zone 61
Figure U. Crown-fire potential, South Zone 61
Figure V. Acres at risk of active crown, passive crown, and surface fire, by forest type and structure, South Zone 62
Figure W-1. Fire start density map displays where the most fire starts have occurred, per square mile, over the last thirty years. Data set from 1970-2000, South Zone, (USDA 2003). 63
Figure W-2. Fire start density map displays where the most fire starts have occurred, per square mile, over the last thirty years. Data set from 1970-2001, South Zone, (USDA 2003). 64

List of Tables

Table 1. Vegetation types used in the Okanogan and Wenatchee National Forests Health Assessment; potential habitats used to assess lynx, flammulated and white-headed woodpecker, and the northern spotted owl. 20
Table 2. Acreage by forest type and density, North Zone 36
Table 3. Acreage by forest type and density, Central Zone 38
Table 4. Acreage by forest type and density, South Zone 40
Table 5. Vegetation types used in the Okanogan and Wenatchee National Forests Health Assessment; potential habitats used to assess lynx, flammulated and white-headed woodpecker, and the northern spotted owl 65
Table 6. Current and projected availability of potential northern spotted owl habitat 66
Table B-1. Effects on wildlife habitat evaluation criteria 88
Table C-1. Acres of dry and mesic forest type 94
Table C-2. Acres of dry and mesic forest type, 1934 95
Table D-1. Time required to complete all harvest and post-harvest treatments 100

Overview

This forest health assessment is organized into five sections. In sections I and II we discuss the recent history of forest health assessments for national forests lands in Washington on the east slopes of the Cascades, along with the current types and levels of management activity. In section III we describe the methods and procedures we used to assemble and evaluate data in this forest health assessment. We discuss the general disturbance ecology and effects of fire, and the forest-wide situations for insects and diseases in section IV. Implications for wildlife resources are discussed at the forest-wide scale, as well. In section V, "Findings," we discuss specific fire, wildlife, and insect-related issues for the North Zone (Methow and Tonasket Ranger Districts), Central Zone (Chelan, Entiat, and Wenatchee River Ranger Districts), and the South Zone (Cle Elum and Naches Ranger Districts). The Leavenworth and Lake Wenatchee Ranger Districts were administratively combined in 2001. The administrative combination is referred to in this document as the Wenatchee River Ranger District. We then present our conclusions. Supporting material is provided in the appendices.

I. Introduction

Much of the Okanogan and Wenatchee National Forests are susceptible to large, severe wildfires. Because of over seventy years of fire exclusion, past timber harvest practices, grazing, and climate, the amount of dense dry and mesic forest capable of supporting epidemic insect and tree diseases has significantly increased during the twentieth century. Dry forests generally occur at mid and lower elevations. They were historically open and often supported an overstory of widely spaced, large, ponderosa pine, western larch, and Douglas-fir trees. Fires were frequent, typically less than 15 years between events, and generally of low severity. Mesic forests generally occur at mid elevations. Pre-settlement mesic forests were often similar in appearance to the adjacent dry forests. Mesic forest types often included a higher proportion of western larch and Douglas-fir. Fires burned less frequently in mesic forest than in dry forest types, often returning in 35 years or less. Fire severity was often mixed in mesic forests, with some lethal and some non-lethal fire effects. Dry and mesic forests are often commingled across a wide elevation band. Where this occurs, fire regimes in both forest types were more similar to dry forests where fire was frequent and of lower intensity (Agee 1998).

The severity and magnitude of wildland fires have been exacerbated in recent years by several conditions:

- Accumulations of dead wood
- Development of dense forests on dry and mesic sites
- Ongoing insect and disease epidemics
- Cumulative effects of several years of drought

As a result of increasing forest density and the accumulated fuels from insect outbreaks in all forest types, extreme fire behavior is more likely when a wildfire occurs. The potential for loss of life and property is unacceptably high from wildfire burning in the wildland urban interface or near the boundaries of the national forest. Fire suppression costs have also been very high. In 2003 the Forest Service spent over $69 million dollars to suppress wildfires that burned nearly 154,000 acres on the Methow Valley, Tonasket, and Wenatchee River Ranger Districts. The risk of wildfire to human life and property and the increasing costs of wildfire suppression are issues of national concern (US GAO 2004).

County commissioners, state legislators, and members of Congress have expressed concerns about the growing threat of wildfire. Residents near national forest boundaries want the risk of wildfire to homes and property reduced. State officials are concerned that wildfire originating on the national forest may burn onto adjacent State Trust lands. Federal officials and the Canadian government are concerned that wildfires in the United States may threaten homes and forest lands north of the international border. Tribal governments are concerned that wildfires may spread from the national forests onto adjacent Tribal lands.

The Okanogan and Wenatchee National Forests span approximately 3.9 million acres of forests, grasslands, and shrublands along the east slopes of the Cascade Mountains. Since the Barker Mountain and Dinkelman fires of the late 1980s, approximately 600,000 acres have burned in wildfires. Lives and homes have been lost. Wildfires have burned forested wildlife habitat and caused irrecoverable economic loss of substantial timber, range, and recreation value.

Previous Assessments

Several forest health assessments have pointed to the developing risk of severe wildfire on national forest lands on the east slope of the Cascades. All point to the elevated, intensifying risks of high severity wildland fire, and the increasing insect and disease-caused mortality on eastern Washington national forest lands.

Hessburg and Flanagan (1991 and 1992) discussed the extent and probable increases of insect and disease-related tree mortality. Their work prompted the Okanogan, Wenatchee, and Colville National Forests to develop the Northeastern Washington National Forest Health Proposal, a Report to the Regional Forester (Shultz et al. 1993). This report discussed the extent of ongoing insect-related mortality and its relation to wildland fire risk. The report noted that nearly 13,000 homes were located near at-risk forested lands, and recommended a program of accelerated treatments using prescribed fire, harvesting, and non-commercial thinning to reduce the risk of fire, insect damage, and forest diseases. Recommendations from the Northeastern Washington National Forest Health Proposal were implemented on a reduced scale. The Eastside Forest Ecosystem Health Assessment, prepared in response to a request by Congressman Foley and Senator Hatfield (Everett et al. 1994), also suggested active management to address growing insect, disease, and fire risks.

These assessments were followed by the more detailed analysis from the Interior Columbia Basin Assessment (USDA FS 1996). Summarizing the findings of the Interior Columbia Basin project, Quigley et al. (1996), concluded that forest vegetation throughout the Basin has become more complex and layered and that shade-tolerant forests have grown more contiguous, creating greater landscape homogeneity which results in a substantial increase in wildfire severity. Most recently, Johnson (2003) has reviewed the condition of forested lands in northeastern Washington managed by the Department of Natural Resources. As has been the case in other assessments, she found forests to be highly susceptible to insects, diseases, and wildfire. All previous forest health assessments have pointed to the elevated and increasing risks of wildland fire, and to increasing insect and disease-caused mortality on eastern Washington national forests lands.

Current Assessment

In response to the 1994 wildland fires, the Wenatchee National Forest developed the Strategy for Management of Dry Forest Vegetation: Okanogan and Wenatchee National Forests (Dry Forest Strategy). The Methow Valley and Tonasket Ranger Districts of the Okanogan National Forest were included in the 2000 Dry Forest Strategy update (USDA FS 2000). The Dry Forest Strategy highlights the role of fire and other disturbances in dry forest types and recommends actions and treatments, such as thinning and prescribed fire, to reduce tree density and fuel accumulations to reduce the risk of severe wildland fire.

In 2002, Forest Supervisor Sonny O'Neal chartered a review of forest health conditions on the Okanogan and Wenatchee National Forests. The review was to focus on areas affected by insect- and disease-related mortality and the associated elevated wildland fire risk. He identified the following objectives for the Forest Health Assessment team:

- Conduct an assessment of the Okanogan and Wenatchee National Forests' health status by focusing on areas with significant tree mortality, fuel buildup, and other high risk characteristics. Include, where necessary, adjacent forest health situations.
- Develop a map outlining current mortality, including the extent of insect and disease presence based on host type.
- Identify alternatives, strategies, or actions, including potential consequences, to move forest health in a positive direction.
- Prepare a report for the Forest line leadership and present this report at the Forest Leadership Team (FLT) meeting.

The Forest Health Assessment Team presented their assessment of forest health conditions to the FLT on March 12, 2003. The FLT requested that additional information on wildlife effects of forest health conditions be incorporated in the assessment. The FLT decided to charter a separate group to meet after the Forest Health Assessment is completed to develop alternatives, strategies, and actions to address perceived threats and risks.

In May of 2004 the Forest Health Assessment was reviewed by a panel of scientists. The science review was managed by the Wenatchee Forestry Sciences Laboratory of the Pacific Northwest Forest and Range Experiment Station. In June and July of 2004 the Forest Health Assessment was updated to address reviewer comments.

This Forest Health Assessment (FHA) is intended to focus on wildland fire and contributory risks. Its purpose is to provide a basis for determining how to prioritize limited staff and budget at the Forest level to make the largest impact. The FHA is necessarily programmatic in nature. It is intended as a catalyst for discussions about program direction and budget. The team fully understands that there are other issues associated with a healthy forest, and that "health," in a broader sense, includes plant community composition, watershed conditions, and the richness of the wildlife communities present within a landscape.

We use the concept of natural variability to assess current conditions in relation to reference conditions and to provide recommendations for future management. Natural variability relies on knowledge of pre-settlement forest structure and composition to increase our understanding of the dynamic nature of landscapes. Detection and explanation of historical trends and variability are essential to informed management (Swetnam, Allen and Betancourt 1999). For the purposes of this document, “pre-settlement” refers to the period of approximately 1600 through 1900.

II. Current Situation

The dry and mesic forest types of the Okanogan and Wenatchee National Forests are susceptible to widespread insect and disease outbreaks and large-scale severe wildfire. Dry forest makes up approximately 1.2 million acres of the 3.9 million acres of the Okanogan and Wenatchee National Forests. Of the dry forest lands, nearly 700,000 acres are dense and at increased risk of stand-replacing wildfire. Mesic forest is also in a condition of elevated risk for stand-replacing wildfire. Of approximately 450,000 acres of mesic forest type, about 335,000 acres are dense and vulnerable to insects, diseases, and wildfire. Dense dry and mesic forest is often found near homes and communities. Nearly 485,000 acres in the wildland-urban interface is dense, dry and mesic forest. About 80% of these acres are in roaded areas.

General guidance provided by the Dry Forest Strategy points vegetation management projects toward reducing fuels, thinning forests, and reducing insects and diseases in the wildland-urban interface (WUI) and in dry forest types. Current management treatments and activities—such as thinning (commercial and non-commercial) and prescribed fire—are beneficial for reducing wildfire risk, insect activity and the amount of disease in the forests. The Dry Forest Strategy is consistent with the Healthy Forests Initiative (Office of the President 2002) and the Healthy Forests Restoration Act (H.R. 1904).

Current Management

During the past decade the Okanogan and Wenatchee National Forests have used commercial timber sales, non-commercial thinning, and prescribed fire to reduce tree stocking and abate fuels. Most projects occurred in dry and mesic forest types, and many were within the WUI. However, despite efforts to proactively address worsening forest health conditions by targeting vegetation management on at-risk sites, the number, severity, and extent of large, severe wildland fires continue unabated.

The average number of acres treated each year by commercial timber harvesting and non-commercial thinning has dropped since the mid-1990s from about 16,000 acres to about 6,000 acres (Figure A) in 2003. Acres treated by commercial timber harvest are shown for each Ranger District, while acres of non-commercial thinning and release were aggregated for all Ranger Districts. There is significant controversy about the role of timber sales on the national forests. This, combined with increased concerns about the impacts of logging on wildlife, soils, fisheries, and recreation resources, and substantially reduced funding for timber sales during the 1990s, have contributed to the decline in the number of acres managed using commercial timber harvest. During the last eleven years funding for non-commercial thinning has steadily declined.

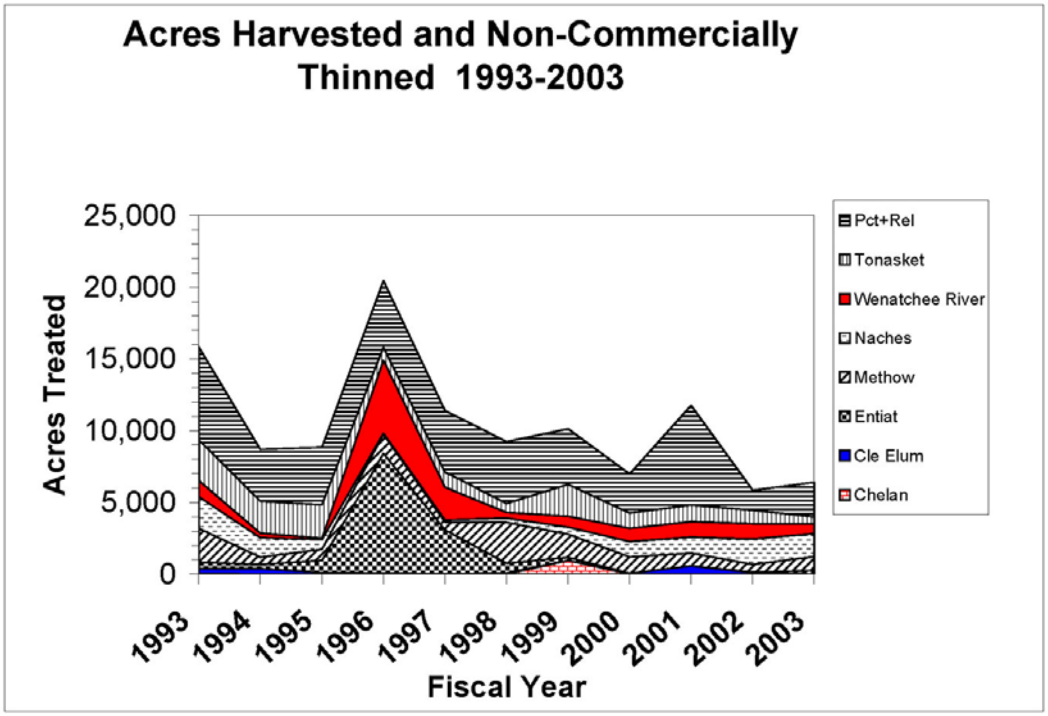


Figure A. Total acres mechanically treated by non-commercial thinning (Pct+Rel) and timber harvest between 1993 and 2003, Okanogan and Wenatchee National Forests

At the same time, the number of acres treated with prescribed fire each year has increased from less than 5,000 acres in the early 1990s to over 16,000 acres in 2003 (Figure B). Because many of the burning, non-commercial thinning, and harvest treatments occur sequentially on the same acres, the overall treatment of acres at risk is actually much less than it appears. For example, the Pendleton Ecosystem Restoration Project on the Wenatchee River Ranger District restored vegetation structure and reduced fuels on about 2,500 acres. Approximately 2,000 acres were commercially thinned. Timber harvest was followed by prescribed burning and non-commercial thinning on most of these acres.

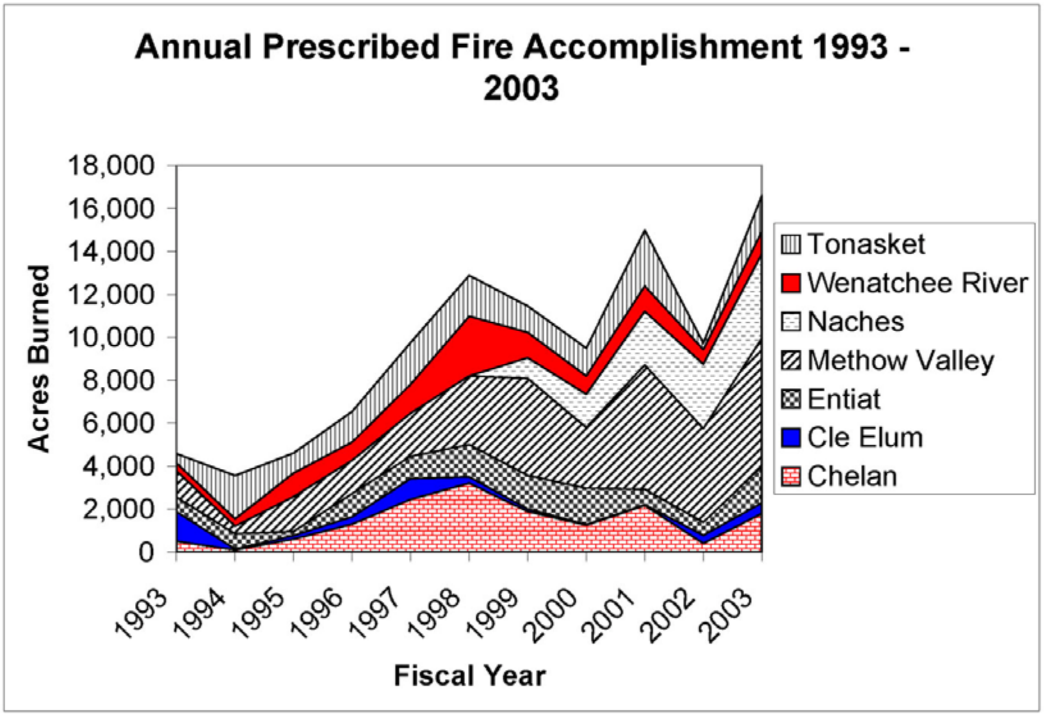


Figure B. Acres treated with prescribed fire between 1993 and 2003, Okanogan and Wenatchee National Forests

Many acres of harvesting and prescribed burning are associated with fuel abatement and salvage operations that follow wildland fire. For instance, the 1994 Tyee Fire burned approximately 86,000 acres on the Entiat Ranger District. About 15,000 acres of the burned forest land were salvaged to reduce fuels, restore low intensity fire regimes and to recover economic timber values.

At the current rate of treatment, each year vegetation and fuels are managed on only about 1% of the forest acreage outside of wilderness. Most of the acres treated are on dry and mesic sites. Since 1990, five of the seven Ranger Districts on the Okanogan and Wenatchee National Forests have experienced large, stand-replacing wildland fires. These fires have burned over nearly 400,000 acres of forest and rangeland. Forest wide, about half of the forest vegetation (51%) is dry and mesic. Slightly less than half (47%) is moist forest type, and there is a small amount (2%) of cold dry forest type (see Figure C).

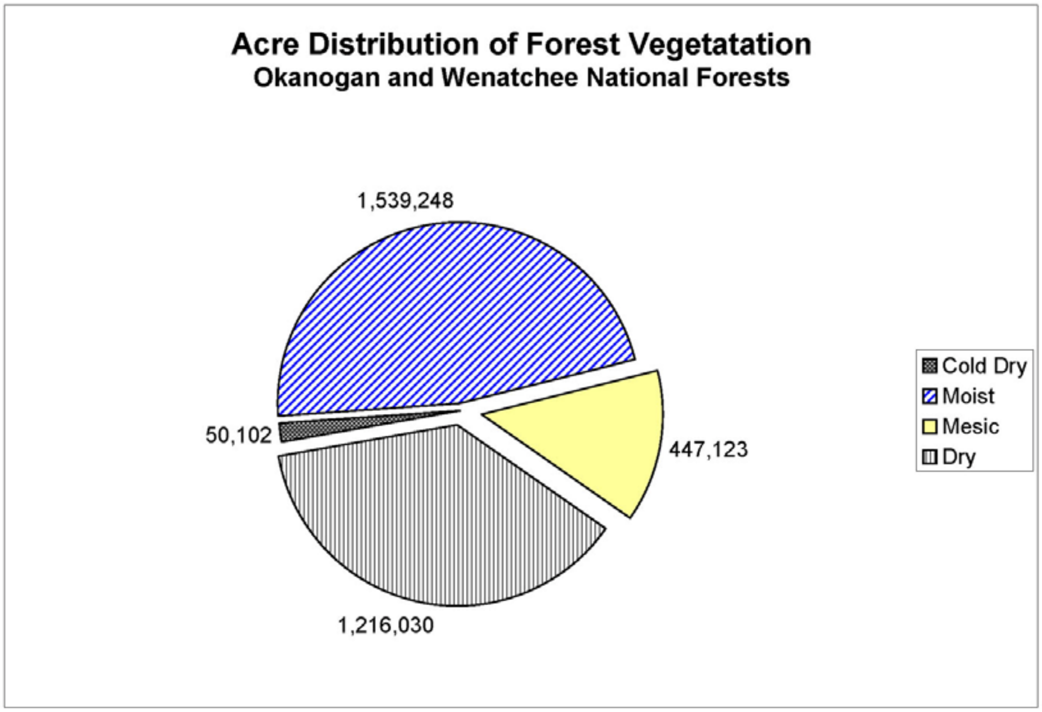


Figure C. Distribution of acres among forest types, Okanogan and Wenatchee National Forests

Sixty-seven percent of the acres burned between 1990 and 2003 were dry and mesic forest. At least one third of these acres were dense forest (see Figure D). Several fires have re-burned areas that burned in previous years. For example, the 2003 Farewell Fire on the Methow Ranger District re-burned portions of the Thirtymile Fire of 2001, and the Thirtymile Fire re-burned portions of the 1994 Thunder Mountain Fire.

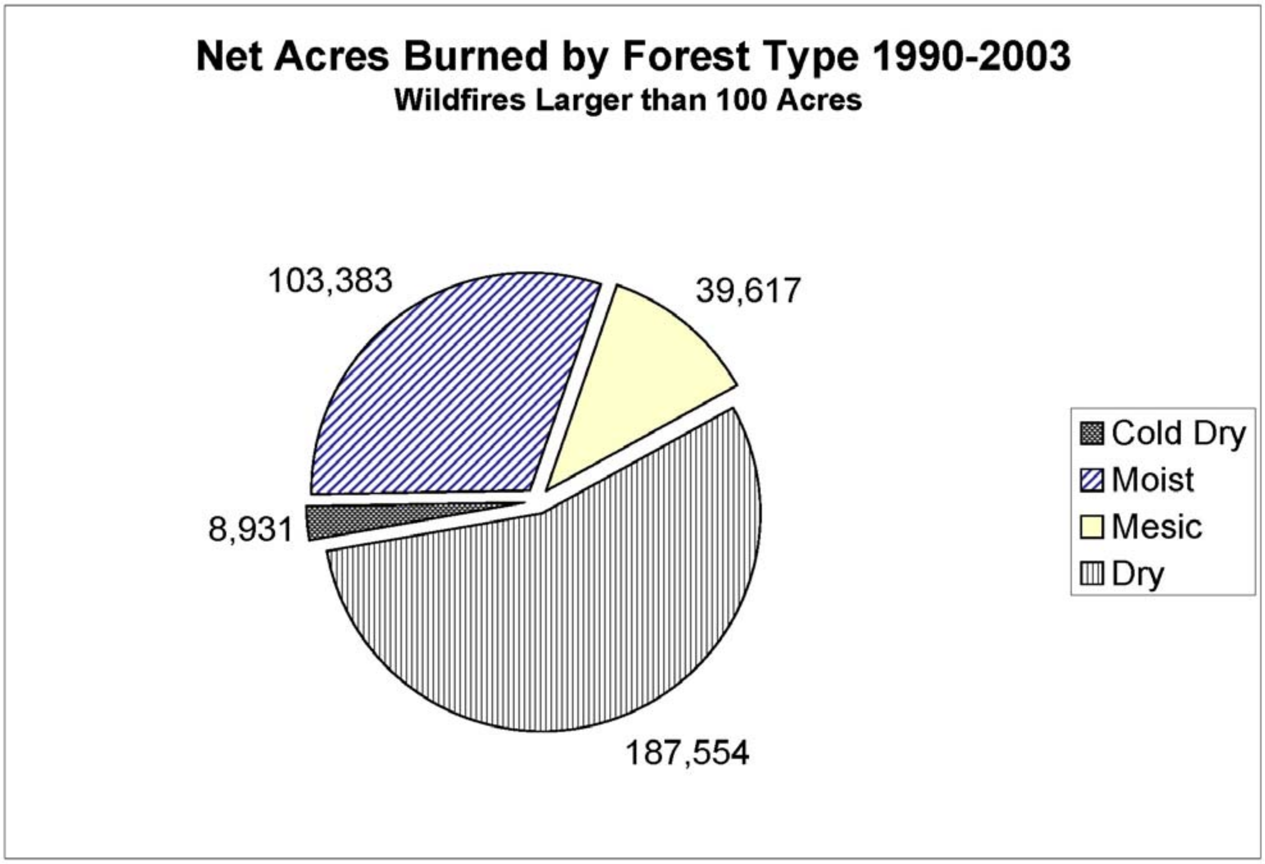


Figure D. Net acres burned, by forest type, between 1990 and 2003 on the Okanogan and Wenatchee National Forests. Only fires larger than 100 acres are included.

Each year since 1985 thousands of acres of forest, particularly on the Methow Valley, Naches, and Tonasket Ranger Districts, have been affected by insect epidemics. Bark beetles have killed thousands of trees, creating large amounts of dead wood that fuel large, severe wildland fires. The greatest bark beetle-caused tree mortality has occurred on the Methow Valley Ranger District, where insects have killed many trees on about 200,000 acres of forested lands. Much of the 2003 Farewell Fire burned through areas of insect-killed forest. Western spruce budworm has heavily defoliated nearly 200,000 acres of forest on the Naches Ranger District during the last three years. Bark beetles are attracted to these stressed stands, and have killed Douglas-firs and true firs on about 18,000 acres.

In the 1970s, 1980s, and 1990s large areas of outbreaks of western spruce budworm defoliation affected many thousands of acres on the Okanogan and Wenatchee National Forests. The 1970s outbreak on the Methow Valley Ranger District and the 1980s outbreak on the Naches Ranger District were suppressed with mixed success. More recently, in 2001 about 18,000 acres of dry forest type on the Methow Valley near Mazama were sprayed to suppress a Douglas-fir tussock moth outbreak. After that, the tussock moth population declined drastically, and the outbreak collapsed in 2001. Stand conditions that precipitated the outbreak were not changed by direct suppression. Epidemics of Douglas-fir tussock moth or western spruce budworm will recur as long as the forest remains in a highly susceptible condition.

III. Procedures and Methods

Methods Used

Several categories of information were addressed in the FHA. In this section, we present information about forest vegetation, insects, tree diseases, fire and fuels risk, and focal species wildlife habitats.

To make the analysis manageable within the time available and also preserve some site specificity, the data were analyzed and displayed in three zones. Zones roughly correspond to substantive changes in major vegetation communities. They also help step down the analysis to administrative units. The three zones are:

1. North Zone: Methow Valley and Tonasket Ranger Districts
2. Central Zone: Chelan, Entiat, and Wenatchee River Ranger Districts
3. South Zone: Cle Elum and Naches Ranger Districts

Forest Vegetation

Characterization of current forest vegetation species and structure was fundamental to the analysis. Shrublands and grasslands were not addressed in the analysis. Forest vegetation was mapped using geographic information system (GIS) covers. Coverages for existing vegetation, elevation from the digital terrain model, and potential natural vegetation (PNV) were combined to create four forest types:

Warm dry/Hot dry forest
Mesic forest
Moist forest
Cold dry forest

The process used to develop these forest types is described in Appendix A. The warm dry/hot dry forest is identical to the existing dry forest covers developed for the Dry Forest Strategy (USDA FS 2000). Crown closure and structure were used to map dense, not dense, small, and large tree dry forest. To derive the mesic, moist, and dry forest types, we used the Neiman classification for the Chelan, Cle Elum, Entiat, and Naches, and Wenatchee River Ranger Districts (Neiman 1998), the Utah State Classification for the Methow Valley and Tonasket Ranger Districts (Bio/West and Utah State University 1999), and the existing dry forest GIS covers developed earlier for the Dry Forest Strategy. Maps of the forest types can be found in the section "Findings." Based on the assessment team's collective experience and knowledge of the area, the vegetation maps appear to be a reasonable reflection of actual conditions.

Insects

Insect-caused tree mortality was analyzed in three steps. (1) Long-term bark beetle-caused mortality was aggregated and analyzed to estimate existing areas of high fuel accumulations. (2) Areas of defoliator activity were analyzed to estimate the extent of insect-caused mortality. (3) Finally, to understand short-term trends, defoliator and bark beetle activity for the past three years was analyzed. Recent insect activity was assumed to be indicative of bark beetle and defoliator trends for the next three to five years.

Insect activity was analyzed using information from the Pacific Northwest Region Annual Aerial Detection Survey from 1980-2002. This data set exists as multiple GIS coverages.

The following criteria, in sequence, were used to identify extensive bark beetle-caused mortality:

1. GIS covers for 1980 to 2002 were used to determine the extent of Douglas-fir beetle, western pine beetle, mountain pine beetle, or spruce beetle activity.
2. Polygons with fewer than ten trees per acre killed by Douglas-fir beetle or fewer than five trees per acre killed by mountain pine beetles were deleted. Because spruce beetle is difficult to detect during aerial survey, any detection of spruce beetle was considered significant and included in the analysis.
3. All bark beetle polygons were aggregated into a single shape file displaying overall bark beetle-caused mortality.
4. The remaining polygons were given a 660-foot buffer.
5. The resulting buffered polygons were merged.
6. Any merged polygon of less than 640 acres in size was deleted from the analysis.

To reduce noise and focus the analysis on areas where substantial amounts of tree killing had occurred, polygons with less than threshold bark beetle-caused mortality were excluded from the analysis. Accumulated mortality in the remaining areas would be most likely to result in significant amounts of down fuel load. Polygons were buffered to capture areas of transitional mortality and to coalesce small dispersed pockets of mortality into landscape units. Aggregated and buffered polygons of fewer than 640 acres were excluded because they did not represent fuel concentrations that would have significant impact at the landscape scale.

Extensive mortality resulting from defoliator insects was estimated as described below. For this analysis, only polygons with heavy defoliation from western spruce budworm were retained.

Based on zone entomologist experience and observed defoliator effects in northeastern Washington, we expect that heavy defoliation by western spruce budworm for three consecutive years would result in 50% mortality of host trees, primarily in the smaller size classes. The following criteria were used to identify extensive western spruce budworm mortality:

1. GIS covers were used to determine locations of three consecutive years of heavy western spruce budworm defoliation.
2. A shape file was created containing only those polygons.
3. Any polygon less than 640 acres in size was deleted from the analysis for reasons discussed above with bark beetle modeling.

Current trends for bark beetles and defoliator insects were analyzed using aerial survey data from 2000, 2001, and 2002. All bark beetle-caused mortality was used in the trend analysis, regardless of the number of trees per acre or polygon size. All heavy defoliation by western spruce budworm was used, regardless of the number of consecutive years or polygon size.

Forest Diseases

Root disease presence was assessed for existing vegetation based on accumulated stand and project level assessments completed by the Wenatchee Service Center.

The extent and effects of white pine blister rust on existing vegetation were determined based on field work by Wenatchee Service Center pathologists.

Dwarf mistletoes are the most common tree diseases on the Okanogan and Wenatchee National Forests. The current extent of dwarf mistletoe infection was determined by evaluating the level of infection reported on the Forest Inventory Continuous Vegetation Survey (CVS) plots. There are 1,458 CVS plots distributed across forested portions of the Okanogan and Wenatchee National Forests on a fixed grid. Dwarf mistletoe distribution was determined only for Douglas-fir and western larch. All other dwarf mistletoes are present only in localized populations, or have limited impact on forest vegetation. About 1,300 CVS plots contain Douglas-fir; about 590 CVS plots contain western larch. Within Congressionally Designated Wilderness, CVS plots are on a 3.4 mile grid. Outside of wilderness plots are located on a 1.7 mile grid.

Fire and Fuels

We evaluated the potential crown-fire risk for the Okanogan and Wenatchee National Forests using the existing crown-fire potential mapping. Conditions conducive to crown fire are: dry fuel moisture, low humidity, high temperatures, heavy fuel accumulation, the presence of ladder fuels, steep slopes, strong winds, unstable atmosphere, and a continuity of coniferous tree crowns (Rothermel 1991, Van Wagner 1977). Crown attributes, such as vertical and horizontal distribution of branches and foliage, make certain coniferous species especially vulnerable to crown fire. Based on Fahnestock (1970), tree species and crown attributes were used to assign a baseline, or intrinsic rate, that identifies the relative vulnerability to crown fires of each vegetation pixel. To account for those crown attributes, forest vegetation maps from February 1996 LANDSAT Thematic Mapper Images with attributes such as cover types, forest structure, number of canopy layers (ladder fuels), and tree canopy were identified as analogues to vertical and horizontal continuity (USDA FS 2002).

From this effort, six relative crown-fire-potential classes were used to rate combinations of the attributes with respect to their intrinsic vulnerability to crown fires: None, Very low, Low, Moderate, High, and Very high. These were then applied to the Okanogan and Wenatchee National Forests on grid maps with 30-meter pixels. Next, the six types used in the Okanogan and Wenatchee National Forests Fire Management Plan (USDA FS 2002) were collapsed into four classes: No risk (“none” in the Fire Management Plan), surface fire (“very low” and “low” in the Fire Management Plan), passive crown fire (“moderate” in the Fire Management Plan), and active crown fire (“high” and “very high” in the Fire Management Plan). The outcome of this mapping effort is displayed in maps in the following sections. Additional details of the crown modeling effort can be found in the Okanogan and Wenatchee National Forests Fire Management Plan.

The next step was to overlay the vegetation layer to stratify the landscape into high, mixed, and low fire severity regimes based on historical conditions described by Agee (1993 and 1994). This allowed us to assign some qualitative level of risk to areas that showed high crown-fire potential. In other words, not all forest vegetation with high crown-fire potential is at high risk of experiencing severe wildland fire (as used here, “high” means probability of yearly large fires). Areas within the low severity fire regime correspond to dry forest vegetation; areas of high crown-fire potential in this historical fire regime are at the highest risk. The mixed severity regime corresponds to areas of mesic forest vegetation and areas of high crown-fire potential are at moderate to high risk. The high severity fire regime corresponds to the cold and moist forest vegetation types; areas of high crown fire potential are at low to moderate risk.

Wildlife Habitats

To gain insight into the roles that fire and other disturbances may play in the condition of wildlife habitats, we used the focal species approach (Lambeck 1997) and evaluation criteria (adapted from Erickson and Toweill 1994). We provide an overview of the focal species approach, including the pros and cons of using it. Our rationale for the selection of the focal species addressed in this assessment is provided in Appendix E.

The focal species approach is an attempt to streamline the assessment of ecological systems by monitoring a subset of species and can be seen as a pragmatic response to dealing with ecosystem complexity (Noon 2003, Roberge and Angelstam 2004). The key characteristic of a focal species is that its status and trend provide insights to the integrity of the larger ecological system to which it belongs (Lambeck 1997, Noss et al. 1997, Andelman et al. 2001, Noon 2003). Focal species serve an umbrella function in terms of encompassing habitats needed for other species, are sensitive to the changes likely to occur in the area, or otherwise serve as an indicator of ecological sustainability (Lambeck et al. 1997, Noss et al. 1997, COS 1999, Andelman et al. 2001). The long-term viability of the focal species is assumed to be representative of a group of species with similar ecological requirements and this group is assumed to respond in a similar manner to environmental change. In addition, the focal species is assumed to have more demanding requirements for factors putting other group members at risk of extinction (Andelman et al. 2001). Focal species are intended to represent ecological conditions that provide for viability; it is not expected that the population dynamics of a focal species would directly represent the population dynamics of another species.

Lindenmayer et al. (2002) pointed out some of the limitations of the focal species concept, including the approach is data-intensive, scientific understanding is lacking for many species, and there is a lack of testing to validate the approach. Lindenmayer et al. (2002) were concerned that the focal species approach not be the only approach used to guide landscape restoration. However, the focal species approach has recently been tested for some wide-ranging carnivores (Carroll et al. 2001) and birds (Watson et al. 2001) with promising results. In addition, Roberge and Angelstam (2004) recently reviewed the umbrella species concept and concluded that the focal species approach seems the most promising because it provides a systematic procedure for selection of umbrella species. The focal species used in this assessment of forest health are consistent with those being recommended for use in the Species Diversity Assessment Process for forest planning in the Pacific Northwest Region of the Forest Service (Region 6) (USDA FS n.d.). The focal species approach is a relatively rigorous way, compared to other approaches, to deal with assessments that involve large numbers of species (Adelman et al. 2001, Roberge and Angelstam 2004).

Because this assessment relied on the focal species selection process being developed for forest planning in Region 6, an overview of the regional process is included. The Region 6 process identifies at-risk species and then groups species based on habitat relationships and other environmental requirements. Then a set of focal species was identified within each group. The intent was to select a set of species that represent the full array of potential species responses to management activities (Raphael et al. 2001). Development of a logical foundation for focal species selection is critical but poorly developed at this time (Noon 2003). Presented below are the criteria used in selecting focal species for forest planning in Region 6. It is expected that as new information becomes available from monitoring and research, that these criteria may need to be revised.

Focal Species Selection Criteria

Primary Criteria

Habitat requirements are most demanding. For example, a species within a large-tree source habitat group that requires the largest trees would be selected over others that use smaller trees. Fine scale habitat needs were also considered, such as those species whose source habitats required features such as snags or burned areas.

Species sensitive to the risk factor(s) that may result in:

- Change in habitat availability.
- Change in habitat effectiveness.
- Population effects.

The risk-factors associated with each species in the group were identified. The sensitivity of each species to forest management activities was then ranked by evaluating the number of risk-factors identified and the breadth of different kinds of risk-factors identified for each species within the group. This provided an index to the sensitivity of each species within the group to the kinds of management activities that occur on national forest lands (Lambeck 1997).

Other Considerations

Species with distribution across the planning area

The range of the selected species needed to overlap with the range of others in the group. For some groups more than one species was selected if species within the group had limited distribution.

Data/information availability

- Species was used as a focal species in another assessment within the same geographic area.
- Species response to management activities, and threats or risks, is known.
- Habitat relationships are defined.

Populations and/or habitats can be most readily monitored

- Monitoring protocols are already established.
- Baseline data are already available.

TES Species

TES species were also given preference as focal species if they were a good representative of the group because these species either have a recovery or conservation plan available.

The focal species that we selected, based on the above process and consistent with Region 6 recommendations, include the flammulated owl *(Otus flammeolus)* and white-headed woodpecker *(Picoides albolarvatus)* which are associated with old-growth ponderosa pine forests in dry forests, the northern spotted owl *(Strix occidentalis caurina)* associated with late-successional mixed conifer forests in mesic and moist forests, and the Canada lynx *(Lynx canadensis)* associated with subalpine fir forests in cold dry forests, (see Appendix A and Appendix E).

The criteria we used to assess focal species wildlife habitats were selected because of their influence on the viability of wildlife species (Samson 2002). Each criterion is described and the procedures used to assess each is presented.

The availability of suitable habitats. Potential habitats were identified for each focal species using the vegetation data developed for this assessment. Table 1 shows which vegetation types were identified as potential suitable habitat for each focal wildlife species.

The sustainability of suitable habitats, as inferred from a departure from the reference condition. Habitat sustainability was inferred from the assessment of current fire disturbance regimes and insect levels, compared to assessments of the range of variability that have been completed for each of the forest types. These assessments are presented in a variety of publications, are cited in Table B-1, and listed at the end of Appendix B.

The juxtaposition of suitable habitats to facilitate movement and dispersal among habitat blocks. The current and historic connectivity of forest types have been evaluated in other assessments, specifically in Hessburg et al. (1999). This information was used to describe the current and projected degree of habitat connectivity for each of the focal species. Additional information was available from an assessment by Halupka (2001) of the distribution and connectivity of suitable spotted owl habitat.

Vegetation type	Potential flammulated and white-headed woodpecker habitat	Potential lynx denning habitat	Potential lynx foraging habitat	Potential spotted owl habitat
Dry-not-dense	X			
Dry dense	X			X
Mesic large dense				X
Mesic dense				X
Moist small dense		X	X	
Moist large		X	X	X
Cold dry		X	X	

Table 1. Vegetation types used in the Okanogan and Wenatchee National Forests Health Assessment; potential habitats used to assess lynx, flammulated and white-headed woodpecker, and the northern spotted owl.

These evaluation criteria were used to assess the current condition of focal species wildlife habitats and to project the likely conditions 20 years from now based on the following:

The current level of resources available to manage vegetation, such as thinning and prescribed fire.

Projected distribution, extent, and severity of wildfires based on the distribution, extent, and severity of wildfires during the past ten years.

The potential consequences of global climate change on the distribution and extent of various forest types.

These evaluation criteria were not used to evaluate a range of management options that could be used to address forest health issues. This was beyond the scope of the objectives given to our assessment team. A separate team will evaluate management options and provide recommendations that may be incorporated into forest plan revisions.

IV. Ecological Processes

In this section we discuss the ecological processes that influence fire, insects, and diseases. We also discuss how wildlife ecology is affected by these disturbances.

Natural Variability and Ecosystem Restoration

Forest managers on the Okanogan and Wenatchee National Forests recognize the importance of ecosystem change over time. To understand ecosystem change, scientists use reconstructions of past forest conditions, records of pre-settlement vegetation structure and species composition, and records of past disturbances. Reconstructions are also a useful tool for managing ecosystems. The range of variability in ecosystem conditions and processes has been described using terms such as "historical," "natural," and "pre-settlement." (Morgan et al. 1994). The concept of natural variability is a key component of ecosystem management. Natural variability concepts have long been implemented in wilderness and park management (Parsons et al. 1999), but recently there have been a proliferation of these concepts in other land management agency reports and publications.

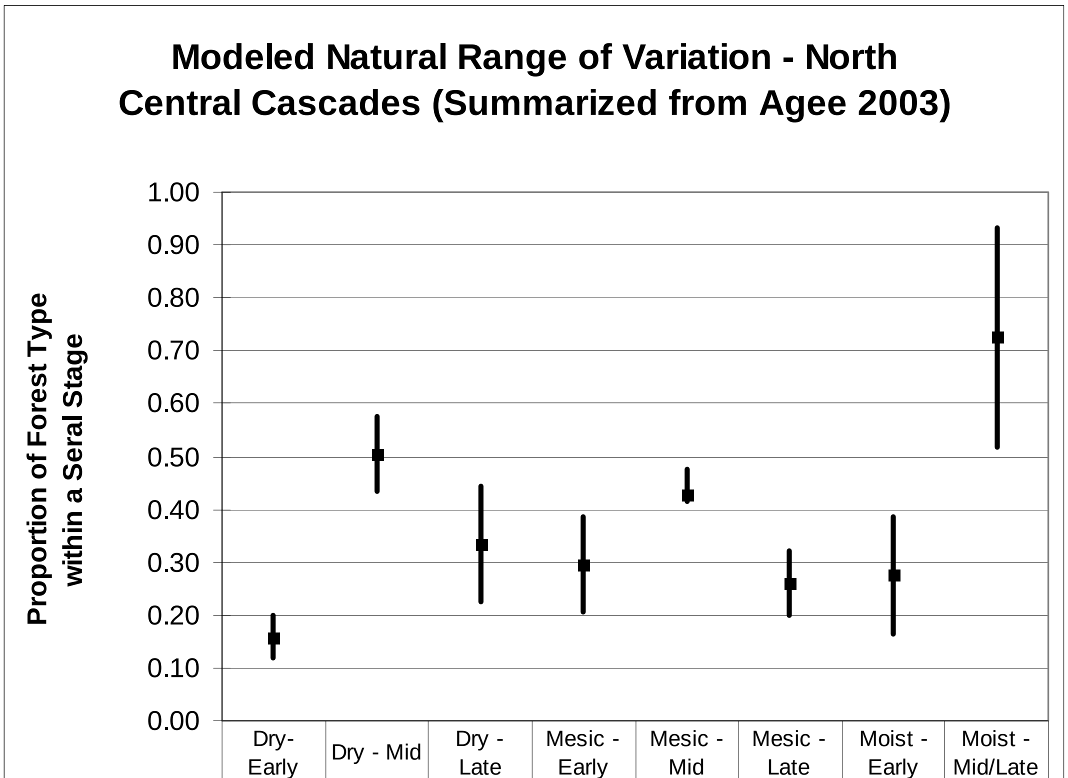
Natural variability refers to the composition, structure, and dynamics of ecosystems before settlement (Morgan et al. 1994, Swanson et al. 1994, Fulé et al. 1997, Landres et al. 1999). Such variations include a diverse array of characteristics, such as tree species composition and density, population sizes of organisms, water temperature, sediment delivery, and so on. The concept of natural variability can be applied at multiple spatial and temporal scales.

Natural variability is a key element of ecological restoration, which is the "process of reestablishing to the extent possible the structure, function, and integrity of indigenous ecosystems" (Society for Ecological Restoration 1993). Ecological restoration is not a fixed set of procedures for land management (Moore et al. 1999), but should be based on a broad scientific framework that includes "ecological fidelity" (structural/compositional replication, functional success, and durability) and mutually beneficial human-wildland interactions (Higgs 1997). In other words, ecological restoration consists not only of restoring ecosystems, but also of developing human uses of wildlands that are in harmony with the disturbance regime of these ecosystems (Society for Ecological Restoration 1993, Moore et al. 1999).

Conditions that occurred under past climactic regimes are not the same as current or future conditions. Pre-settlement data has been used for guiding current management activities (Harrod et al. 1999), but this is likely a conservative approach. Descriptions of natural variability often rely on data from the pre-settlement period, when conditions were cooler and more moist than our current climate (Millar and Woolfenden 1999). Climate variability expressed as changes in temperature and moisture that have occurred since the pre-settlement period may ultimately affect the success of contemporary management strategies (Millar and Woolfenden 1999). Millar (2003b) argues that because of changes in climate, "a goal of returning species to former conditions" and geographic distributions may be difficult or impossible to achieve.

Agee (2003) used published historical fire return intervals and expected fire effects to determine the natural range of variability for forested ecosystems in the central eastern Cascade Mountains between the north shore of Lake Chelan and the northern boundary of the Yakama Reservation. Agee noted that “the application of a concept like historical range of variability implies that the forest landscape possesses at least-quasi equilibrium properties.” He cautioned that “any reconstruction of historical ranges must be interpreted in the context of changing climate.” Ranges of structural classes presented by Agee are aggregated into forest types and summarized below (Figure E).

Agee did not address density per se in his analysis. Based on fire regimes, it is likely that much of the dry and mesic forest type in all seral stages (early, middle, and late) would have had low numbers of trees, and would therefore not be categorized as “dense” forest. Conversely, much of the moist forest type which is characterized by infrequent, severe fire events, would have had high numbers of trees in all by the early seral stages. Agee’s model did not consider the effects of fire in adjacent forest types. For example, more frequent fire in dry or mesic forest may influence the fire return and intensity of fire in moist forest located immediately adjacent to and upslope.



	Dry-Early	Dry - Mid	Dry - Late	Mesic - Early	Mesic - Mid	Mesic - Late	Moist - Early	Moist - Mid/Late
Low Range	0.12	0.43	0.23	0.21	0.42	0.20	0.16	0.52
High Range	0.20	0.58	0.44	0.39	0.48	0.32	0.39	0.93
■ Mean	0.16	0.51	0.33	0.30	0.43	0.26	0.28	0.73

Figure E. Modeled natural range of variation for the north central Cascades of Washington (summarized from Agee 2003)

Disturbance Regimes and Disturbance Processes

Disturbances caused by fire, insects, and forest diseases are important in describing natural variability. On the Okanogan and Wenatchee National Forests, forest ecosystems develop in concert with, and are subject to, a variety of natural, introduced, and altered disturbance regimes. Fire is a classic disturbance agent. A fire regime, which is a type of disturbance regime, refers to an integration of attributes including frequency, intensity, severity, duration, synergistic effects with other disturbances, and extent. For example, the low severity fire regime is characterized by high frequency fire return and low fire intensity. Severity is a measure of potential damage to plants, soils, and other ecosystem components. Intensity refers to the amount of energy released when fuels are consumed.

Natural disturbances on the Okanogan and Wenatchee National Forests include fire, insects, diseases, wind throw, wild herbivores, and weather. Natural fire includes both aboriginal and lightning fires. Introduced disturbances include livestock grazing, mining, timber harvesting, road construction, and modern human-caused fires. Pre-settlement disturbance regimes have been altered by management activities. Fire exclusion removed a significant disturbance from eastern Washington landscapes. In addition, climatic changes, livestock grazing, and timber harvesting have altered vegetation and associated fuels. These have caused large changes in disturbance regimes from pre-settlement times.

The degree to which a disturbance regime within a watershed or drainage has been altered depends on a combination of past management activities, occurrence of insects and disease, wildfire events, and other factors that have resulted in large accumulations of biomass in dry and mesic forests. Dale et al. (2001) note that the "natural disturbances having the greatest effects on forest [in the United States] include fire, drought, introduced species, insect and pathogen outbreaks . . . ." They predict that global climate changes will influence disturbance regimes when temperature and moisture varies from conditions experienced in the past.

Recent work evaluating the effects of climate change suggests warmer conditions may result in 10% or more increases in acres burned (Dale et al. 2001). Likewise, predicted increases in mean annual temperature and altered precipitation regimes over the next 50 years could result in changes in the relative location and abundance of forest types on the landscape (Bachelet and Neilson 2000, Neilson 2003). Neilson and Chaney (1997) suggest that the cold and moist forests dominated by spruce-fir species may decline substantially in the west. Millar (2003a and 2003b) has shown that over the past several thousand years climate has profoundly shaped vegetation. In past millennia abrupt changes in climate that affect disturbance regimes and ecological processes have occurred in time frames of years and decades.

Insect and Disease Processes

Insects and diseases are major influences on forest ecosystem function. On the Okanogan and Wenatchee National Forests, insects and disease continually reshape forest structures. The abundance and vigor of these disturbance agents are likewise influenced by forest productivity (site potential), structure, composition, weather, and climate.

Death and growth reduction are among the effects that forest diseases can have on trees. Tree killing by disease is almost always chronic in nature and typically goes unnoticed by casual observers. Unlike some species of insects and fires, diseases are not typically responsible for rapid accumulations of dead trees over large contiguous areas. Forest tree diseases were not subject to detailed analysis for the assessment because even though they are indeed very widespread throughout the Forests they typically do not cause large numbers of trees to die on large contiguous areas as does wildfire and some forest insects. Forest diseases kill great numbers of trees annually and cause other effects to the infected trees but the effects of diseases tend to be spread diffusely over the entire forests. Disease effects were considered to largely be outside the scope of the assessment charter.

Bark Beetles

Bark beetles play an important role in thinning overstocked stands of trees. Generally the most stressed trees are killed first. Rapid changes in both stand structure and tree species composition may result from bark beetle outbreaks. Trees killed by bark beetles add to rapid accumulation of fuels when dead needles and twigs fall to the ground. Large fuels increase as dead trees fall over a period of five to fifteen years. Warmer climatic conditions may increase the acreage affected by bark beetle outbreaks over current levels. Current levels of bark beetles, though at epidemic levels in lodgepole pine and Englemann spruce, are within the pre-settlement natural range of variability in the moist forest type. If predicted climatic warming materializes, it could result in increased bark beetle activity Wagner (2003).

Mountain Pine Beetle

The interaction of fire and bark beetles largely controls the dynamics of lodgepole pine ecosystems (Geiszler et al. 1980). Mountain pine beetle outbreaks commonly occur in lodgepole pine stands older than 80 years, and are closely associated with overstocking and drought (Edmonds et al. 2000). Mountain pine beetles typically infest live trees. Beetles colonize the largest trees first, and productive sites tend to have more intense infestations (Cole and Amman 1980). If a mountain pine beetle outbreak is followed by fire, abundant lodgepole pine regeneration results. The outbreak that continues today on the Tonasket and Methow Valley Ranger Districts began in the mid-1980s.

Spruce Beetle

Spruce beetles preferentially infest recently windthrown, broken, or severely stressed trees (Furniss and Carolin 1977, Safranyik 1995). When a large amount of windthrow or tree damage allows the beetle population to increase rapidly, an outbreak can result, particularly if windthrow occurs in overstocked spruce stands during times of drought (Edmonds et al. 2000). Beetles colonize the largest trees first, and may eventually kill all spruce larger than eight inches in diameter. Outbreaks can be prevented or reduced by removing blowdown before beetles emerge. After a large outbreak is underway there is no effective control. If a spruce beetle outbreak is followed by fire, usually abundant lodgepole pine and sometimes western larch regeneration results. If fire does not follow the outbreak, the resulting stand will consist of spruce that were too small to be colonized by beetles, and regeneration of spruce and subalpine fir. Also in the absence of fire, larch on the lower elevation spruce sites will be sparse.

Douglas-Fir Beetle

Douglas-fir beetles, like spruce beetles, preferentially infest recently windthrown, storm-damaged, or severely stressed trees (Rudinsky 1966, Furniss and Carolin 1977). Outbreaks usually occur following extensive windthrow or intense defoliation. Trees larger than 15 inches in diameter are attacked first. Beetles are also attracted to trees that are weakened by root disease. In eastern Washington, outbreaks initiated by blowdown or fire last an average of four years (Flanagan 1999). However, drought, defoliation, or a new pulse of blowdown or fire damage may cause an outbreak to last longer. Vigorous Douglas-firs can resist bark beetle attack unless the beetle population is extremely high (Furniss et al. 1981). Outbreaks can be prevented or reduced by removing blowdown or damaged trees before occupying beetles emerge. As with the spruce beetle, when a large outbreak is underway there is no effective control. Small, high-value sites may receive some protection by use of anti-aggregant pheromones.

Fir Engraver

Fir engraver *(Scolytus ventralis)* is a native bark beetle that may attack any species of true fir. On the Okanogan and Wenatchee National Forests, it is most commonly found in grand fir. It can be aggressive, but it rarely attacks a host that is not already severely weakened. It often attacks trees affected by root disease. Sometimes only portions of the host tree will be attacked, resulting in top kill or strip kill.

Defoliators

Native defoliating insects, such as western spruce budworm and Douglas-fir tussock moth, are present in host forest types at all times. Defoliation by endemic levels of these insects is not harmful to the tree, and is an important regulator of forest primary production. After light defoliation, photosynthesis of the remaining previously-shaded foliage increases. The photosynthetic capacity of the tree is not diminished in the same relative proportions as the loss of foliage when low intensity defoliation occurs (Webb 1978). A tree with less than 20% defoliation is almost never killed.

One year of total defoliation is often sufficient to kill a tree, but direct tree mortality drops dramatically if even 1% of the foliage remains (Wickman 1978). Trees are killed directly when severe defoliation is persistent over several years. Defoliation also weakens the tree, making it more susceptible to bark beetles (Edmonds 2000) Growth loss and top kill commonly result from heavy or repeated defoliation. The presence of root diseases as weakening agents also increases the likelihood of tree mortality from defoliation. Trees killed by the combination of defoliators and bark beetles will eventually fall, contributing to large fuels on the forest floor.

Predators and weather control endemic populations of defoliating insects. When host material is present, populations can build to outbreak levels. Forests with multiple canopy layers and large numbers of host species trees are the most susceptible to defoliators (Brookes et al. 1985, 1987). They note that the "ecological niche of the budworm has greatly expanded" since the reference conditions of pre-settlement times (Swetnam et. al 1999). During the twentieth century dense, multi-canopy climax forest communities composed of shade tolerant Douglas-fir and grand fir have developed on dry and mesic sites. Anderson et al. (1987) found that the duration and severity of western spruce budworm outbreaks increased in western Montana and the Blue Mountains of Oregon during the twentieth century, following the invasion of dry and mesic forest sites that were previously occupied by later seral Douglas-fir and grand fir. If long term climate conditions trend toward warmer conditions, this will result in greater tree mortality. The frequency and duration of outbreaks may also be affected.

Western Spruce Budworm

Western spruce budworm feeds on Douglas-fir, grand fir, other true firs, and occasionally other species, such as spruce and larch. Western spruce budworm outbreaks generally last for 7-10 years, but may last twenty years or more. Budworm outbreaks occur over a wide range of forest types, from warm dry Douglas-fir to cool moist subalpine fir or spruce, or both. Wherever outbreaks occur, stressed host trees are a common feature (Wulf and Cates 1987). Warm dry sites are more susceptible to outbreaks and suffer more damage than cool, dry sites. Dense, multi-storied stands of Douglas-fir or true fir are the most hospitable for budworm. The adult moths prefer mature trees for egg-laying. As young larvae disperse, they fall onto smaller host trees. On dry sites, dense multi-storied stands of host species can sustain damaging budworm populations for decades. Thinning and other treatments implemented at a landscape scale that reduce canopy complexity and favor non-host species may reduce or interrupt outbreaks.

Douglas-Fir Tussock Moth

Douglas-fir tussock moth feeds on Douglas-fir, grand fir, and white fir. Unlike western spruce budworm outbreaks, which may last for many years or decades, Douglas-fir tussock moth outbreaks tend to be short-lived (four years or less). Like budworm, tussock moth outbreaks recur periodically in susceptible stands (Mason and Luck 1978). Warm dry sites are more susceptible to outbreaks and suffer more damage than cool, dry sites. As with budworm, dense, multi-storied stands of Douglas-fir or true fir are the most hospitable for tussock moth. Young larvae disperse with prevailing winds or simply fall from the tops of trees onto smaller host trees below. As with western spruce budworm, thinning and other treatments that reduce stand complexity and that favor non-host conifers at a landscape scale may reduce the intensity and extent of Douglas fir tussock moth outbreaks.

Dwarf Mistletoes

Dwarf mistletoes are parasitic plants that affect host trees by reallocating water and nutrients. They cause deformation, growth loss, and premature death of the host tree. Dwarf mistletoe infestations develop and spread relatively slowly in trees and stands when compared to the spread rates of many insect species. On the Okanogan and Wenatchee National Forests these parasites occur on Douglas-fir, western larch, ponderosa pine, lodgepole pine, and, less commonly, on hemlocks and grand fir. The most widespread and severe damage occurs on Douglas-fir and western larch. Douglas-fir dwarf mistletoe is abundant in the dry and mesic forest types. It becomes less frequent in the moist forest type because Douglas-fir, its host, diminishes in abundance.

Dwarf mistletoe infection of Douglas-fir results in growth rate reductions, distorted growths, top-killing, and premature tree death. Infection by dwarf mistletoes, and especially Douglas-fir dwarf mistletoe, increases wildfire hazard by increasing the vertical continuity, quantity, distribution, and flammability of fuel (Wicker and Leaphart, 1976) (Tinnin and Knutson, 1980). Douglas-fir dwarf mistletoe is the most lethal of the mistletoes that occur on the Okanogan and Wenatchee National Forests. Tree killing by this mistletoe is chronic and develops slowly. Populations of Douglas-fir on dry sites are particularly affected. Concentrations of Douglas-firs killed by dwarf mistletoe tend to be localized.

Heavily infected branches are very prone to breakage on all tree species; however, infected branches on western larch are especially likely to break (Hadfield 1999). Dwarf mistletoe infections spread readily from tree to tree. However, because dwarf mistletoe is species-specific, dwarf mistletoe from one tree species rarely infect a different tree species.

Historically, wildfires have been the most important single factor governing the distribution and abundance of dwarf mistletoes (Alexander and Hawksworth 1975). Mistletoe infections cause low branches to persist, creating fire ladders that facilitate movement of ground fires into tree crowns. The brooms in infected branches contain dead needles and resin accumulations that make them highly flammable. Fire results in high rates of tree mortality when infected branches ignite. Elevated foliage and twig biomass in infected branches facilitates rapid spread of fire through tree crowns.

Six species of dwarf mistletoe are present on the Okanogan and Wenatchee National Forests. In this assessment, we address only Douglas-fir dwarf mistletoe and larch dwarf mistletoe, which are the most abundant and damaging. In these species, infection causes growth reduction, distorted growth, and premature tree death. Forest inventory data reveal that 51% of the plots with Douglas-fir present are infested by Douglas-fir dwarf mistletoe and 50% of the plots containing larch have larch dwarf mistletoe infestations.

Other Tree Diseases

Several species of root disease fungi affect trees on the Okanogan and Wenatchee National Forests. Root diseases cause chronic, as opposed to acute, mortality. As a result of management actions, root disease mortality has increased in all forest types, with the possible exception of the whitebark pine and subalpine larch series in the cold dry forest type. Fire exclusion and selective harvesting have increased stocking of shade-tolerant, root disease-susceptible species. The largest increases in root disease incidence have occurred in the Douglas-fir and grand fir series and in the warmer drier plant associations in the subalpine fir series within the moist and mesic forest types. However, even in these series root disease-induced tree mortality is localized and chronic, typically involving less than one tree per acre per year.

White pine blister rust is a non-native disease that arrived in northeastern Washington in the early twentieth century. It affects western white pine and whitebark pine, which are minor tree species on the Okanogan and Wenatchee National Forests found primarily within the moist and cold dry forest types. Stands of five-needle pines have been seriously depleted by white pine blister rust. All white pine and whitebark pine stands on the Forests have some rust infection. Mortality was most severe in the 1930s and 1940s when the most susceptible trees were severely infected and died quickly. As a result of about 80 years of interaction between the fungus and the host trees, many of the five-needle pines in existing stands have some genetic resistance to the rust.

Fire Regimes and Fire Processes

Many changes in forest structure and composition can be attributed to alterations of disturbance regimes. To better understand such changes, it is useful to first classify forest types into one of three major fire regimes:

1. Low severity/non-lethal: High frequency, low intensity fire that maintained open park-like stands dominated by ponderosa pine on the majority of the dry forest landscape. Typical in all dry forests and some mesic forests.
2. Mixed severity/moderate: Some high frequency, some low frequency fire; mixed high and

low intensity; forest stands consisted of open park-like conditions and some even-aged patches that result from fire. Common in areas in transition between dry and moist.
3. High severity/lethal: low frequency, high intensity fire that created large patches of even-aged stands across the landscape. Found in the cool, moist, high-elevation forests.

This classification gives us three critical pieces of information (Agee 2002):
1. The historical role that fire played in a given ecosystem.
2. The condition of the ecosystems which experience fire exclusion in areas where fire was historically frequent, as well as where it was not.
3. The challenges and opportunities in determining how to best manage future fires.

We use this information to develop forest and resource management plans: "the critical factor in deciding where to invest management resources is a forest's historical fire regime" (Agee 2002). The interaction between climate, vegetation type structure, fire severity, and fire frequency determine the fire regime.

Low severity fire regime/dry forest type. Forest landscape structure and composition have been most altered in the low severity fire regime. Before settlement, dry forest types experienced frequent (<35 yrs) fires. These frequent, low intensity fires killed smaller trees and maintained open, park-like stands of early seral, fire-tolerant ponderosa pine on the majority of the dry forest landscape (Agee 1993, 1994; Everett et al. 2000). Suckley and Cooper (1860) reported that forests east of Mount Adams between 2,500 and 5,000 feet in elevation consisted of very large pines "usually over a hundred feet high, with a straight trunk three to five feet thick, branching at the height of about forty feet." They reported that this forest type continued north to the Okanogan River. Suckley and Cooper predicted almost 150 years ago that "the cessation of fires on the dry plains will be followed by . . ." an ". . . increase in forest in such places" (Suckley, 10-11). As they predicted, fire exclusion has contributed to changes in forest composition and density. Selective logging that removed larger pines and the absence of frequent low intensity fire have allowed shade-tolerant and fire-intolerant species such as grand fir and Douglas-fir to replace pine as the dominant species.

Forest density and structure have also been changed by fire exclusion. Open park-like forests have largely been replaced by dense stands of multiple canopy layers. As a result, lethal crown fires are now common in dry forest types on the Okanogan and Wenatchee National Forests. Today's crown fires in dry forests are both weather and fuel driven, but historically they were nearly absent in the face of severe fire weather because of the lack of surface and crown fuels (Agee 1997). The early USGS quads where forest types were mapped showed patches of stand replacement fire, which were confined to mesic and wet forests (Agee 1994).

High severity fire regime/cold, moist forest type. Forest landscape structure and composition has been least altered within the high fire regime (Agee 1994). Historically, the cold, moist forest types within this regime underwent infrequent fires with return intervals usually greater than 100 years. Some parts of these forest types, however, experienced more frequent fires. Work by the Wenatchee Forestry Sciences Laboratory suggests that the fire returns in the Meadows area of the Tonasket and Methow Valley Ranger Districts and in subalpine forests on the Entiat Ranger District averaged about 93 years (Schellhaas et al. 2001). They found longer fire return intervals of

42 to 291 years in areas of highly dissected landscape on the Entiat Ranger District and shorter intervals of 28 to 107 years on the Tonasket and Methow Valley Ranger Districts. Schellhaas et al. speculated that the notably shorter intervals observed on the Okanogan are expected given the somewhat drier vegetative conditions and lack of barriers to fire spread." Fahnestock (1976) reported the fire return period in cold, moist forest types in the Pasayten Wilderness was in excess of 200 years. In cold, moist forest types, regardless of the interval, fires were intense and largely stand-replacing. Large severely burned patches of landscape were typical for lodgepole pine/subalpine fir forests (Agee 1993, 2002). The result was a landscape of different even-age patches (thousands of acres in size) rather than the open, park-like structure in the dry forest types.

Riparian areas are a special case. Everett et al. (2003) found that riparian areas in dry forests in north central Washington burned at approximately the same frequency as adjacent Douglas-fir upland forest. Because of readily available moisture and generally cooler and more favorable growing conditions, forested riparian areas in mid and lower elevations accumulate biomass more rapidly than adjacent upland forest. They speculated that when riparian areas burn, energy release is greater, and the local effects may be more severe. Riparian areas containing large amounts of dead or down material have also been shown to provide pathways for fire to traverse landscapes that otherwise have low fuel loadings and that are resistant to fire spread (Agee 1998).

In the cold, moist forest types, the period of fire exclusion has not led to uncharacteristic fuel buildup. However, the general exclusion of fire over the last century has created more homogeneous forest conditions than existed before settlement. This increases the opportunity for crown fires over very large areas. Agee (2003) and Everett et al. (2000) suggest that the area of early seral forest typified by stem exclusion and stand initiation structure is currently less than what existed at the time of settlement for forests in the central Cascades of Washington (Figure E). Based on work by Schellhaas et al. (2001) and on local experience in eastern Washington forests, the Forest Health Assessment team believes this is likely to be the case for most of the Okanogan and Wenatchee National Forests. Hann et al. (1997), however, suggest that early seral forest is not significantly different from pre-settlement conditions in most Columbia Basin subalpine forests. Fire occurrence in the cold and moist forest types is largely weather driven, rather than fuel driven (Agee 1997). In years of average weather conditions, fire behavior does not appear to be affected by forest structure (Romme and Despain 1989); older stands, often with insect damage, support crown fire, while younger stands do not (Agee 1997).

Mixed fire regime/mesic forest type. Forest landscape, structure, and composition have been moderately to highly altered within the mixed severity fire regime. Historically, mesic forest types were a complex patchwork of open to closed forest types. Topography that facilitated movement of lightning or aboriginal-set fires from lower elevation dry forests, or the presence of a large aboriginal population that used fire as a tool, resulted in predominantly open mesic forest types. Changes to forest structure, composition, and density in this fire regime may or may not be as dramatic as those in the low severity fire regime, depending on local conditions.

Many mesic forest types support dense and multi-layered stands that are located immediately adjacent to, or upslope from, altered dry forest types. As discussed above, many riparian forests located within dry forest types support vegetation typical of mesic forest. These forests have a greater potential for being burned by crown fire that initiates from nearby dry forest types. Fire in mesic forest types located upslope from or adjacent to dense dry forest type is probably driven by both fuels and weather.

Wildlife Ecology and Processes

In this section we describe the role of ecosystem disturbance in the ecology of focal wildlife species: the flammulated owl, white-headed woodpecker, northern spotted owl, and Canada lynx. These species are of conservation concern and interest on the Okanogan and Wenatchee National Forests.

The impact of climate change on wildlife habitats and populations is an important and emerging issue (Karieva et al. 1993). Because of animals' habitat preferences, most projections of animal responses to climate change assume that changes in animal distribution will follow changes in plant distribution. While this may be true for some species, it may be only part of the picture. Some animal species may change their distributions in response to local climates and their physiological tolerances (Hart and Shaw 1995). Shifting distributions of species can result in changes in species interactions that influence their survival (Martin 2001). It is beyond the scope of this assessment to provide a detailed and complex analysis of the potential effects of global climate change on focal wildlife species and their habitats. However, we did consider the potential influences that global climate changes could have on the sustainability of focal species wildlife habitats in a very general manner.

Flammulated Owl and White-Headed Woodpecker—Old Growth Ponderosa Pine Forest Habitats

Dry forests provide habitat for flammulated owls and white-headed woodpeckers. These species are associated with old-growth ponderosa pine forests whose structure is largely maintained by a high frequency, low intensity fire regime (Agee 1993). Flammulated owls nest and forage predominately in old-growth ponderosa pine forests (Bull et al. 1990). Wright et al. (1997) found many patches of old growth ponderosa pine that seemed suitable but were not occupied by flammulated owls. Occupied patches were in a landscape dominated by open-canopy pine forests with some small dense thickets, essentially the opposite of much of the current dry forest landscape. White-headed woodpeckers are also associated with low elevation ponderosa pine forests and use large ponderosa pine trees and snags as nesting habitat (Dixon 1995, Marshall 1997). We chose these two species because they represent a wider range of dry forest habitats than either one did individually (Appendix E).

The flammulated owl was identified as a management requirement species in the Northwest Forest Plan (USDA and USDI 1994) and as a focal species in the East Cascades Province Landbird Conservation Plan (Partners in Flight 2001). The white-headed woodpecker was listed as a management indicator species in the Okanogan and Wenatchee National Forest Land and Resource Management Plans, as a management requirement species in the Northwest Forest Plan (as amended 2000), and as a focal species in the East Cascades Province Landbird Conservation Plan (Partners in Flight 2001). In addition, both species were recommended as focal species for forest planning (USDA FS n.d.).

Limited information is available about the effects of fires on white-headed woodpeckers and flammulated owls. Monitoring of bird populations in dry forest landscapes in areas that have and have not experienced stand-replacement fires has been ongoing since 1997. Preliminary results suggest that white-headed woodpecker numbers are higher within unburned dry forests than in areas with stand-replacement fires (Haggard and Gaines 2001). In the stand-replacement fires that occurred in 1994 on the Leavenworth Ranger District, post-fire monitoring indicated that white-headed woodpeckers were present but no nests were detected in two years of monitoring (Haggard and Gaines 2001). However, Saab and Dudley (1998) did report a low number of successful white-headed woodpecker nests following a stand-replacement fire. Understory fire may enhance the characteristics of ponderosa pine forests for nesting, provide openings for foraging, and set the landscape context for occupancy by flammulated owls (Wright et al. 1997, Lyon et al. 2000). It is unknown how flammulated owls may react to stand-replacement fires but we assumed that these areas would not provide habitat during the timeframes considered in this assessment. Both of these species would benefit from the use of prescribed fires used to restore pre-settlement disturbance regimes within dry and mesic forests (Marshall 1997, Wright et al. 1997).

Both flammulated owls and white-headed woodpeckers forage on insects and nest in cavities excavated in snags. These snags are often created by forest insects and diseases. As secondary cavity nesters, flammulated owls rely on cavities created by other species. Flammulated owls eat primarily noctuid moths early in the breeding season, and orthopterans later (Goggans 1986, Reynolds and Linkhart 1987). White-headed woodpeckers use a wide variety of foraging strategies and consume both animal and plant foods. Insects documented as prey species include scolytid beetles (Ligon 1973), bark beetles, cicadas, and spruce budworms (Dixon 1995). Complex relationships exist between trees killed by insects and diseases, the foraging and nesting ecology of primary and secondary cavity users, and the influence of avian foraging on insect populations (see Thomas 2002 for an overview), much of which we are only beginning to understand.

Northern Spotted Owl—Mixed Conifer Late-Successional Forest Habitats

The northern spotted owl was selected as a focal species because of its association with late-successional forests and its sensitivity to forest management (as summarized in Thomas et al. 1990), because is has been used as an indicator species for old growth ecosystems (USDA FS 1990), and it was selected as a species to monitor the effectiveness of the Northwest Forest Plan (Lint et al. 1999).

Suitable habitat for the northern spotted owl has been identified as having the following characteristics: a high canopy closure (>60%), multiple layers, large residual old trees, snags, and downed logs (Buchanan et al. 1995). Approximately 160 spotted owl activity centers have been located on the Okanogan and Wenatchee National Forests. The northern spotted owl is currently federally listed as a threatened species. Recently, monitoring of spotted owls has indicated a fairly sharp decline in their population on the east side of the Cascades (Forsman et al. 2002). Potential reasons for this decline include increased numbers of barred owls *(Strix varia)* and timber harvest on non-federal lands (Forsman et al. 2002).

The barred owl has continued to expand its range throughout the Pacific Northwest and appears to be displacing spotted owls (Kelly et al. 2003). Interspecific competition for space and food resources has been documented in forests of western Oregon and Washington (Herter and Hicks 2002, Hamer et al. 2001, Kelley et al. 2003, Pearson and Livezey 2003). It is unknown how interspecific competition occurs with forests on the east side of the Cascades or how dry and mesic forest restoration may influence these interactions. Therefore, any assessment of potential affects of forest health on spotted and barred owl competition would be highly speculative and is not addressed further in this assessment.

The distribution of the northern spotted owl within the assessment area includes all of the forest types below 5,000 feet in the Chelan, Entiat, Naches, Yakima, Wenatchee, and portions of the Methow, sub-basins. Spotted owls are not distributed to the east of the Methow and Chewuch rivers or on the Tonasket Ranger District. Since implementation of the Northwest Forest Plan, wildfires have had the single greatest impact on the distribution of suitable spotted owl habitat on the Wenatchee National Forest (Halupka 2001). Between 1994 and 2001 approximately 10,000 acres of critical habitat have burned.

Limited information is available about the effects of fires on northern spotted owls. Bond et al. (2002) hypothesized that spotted owls have the ability to withstand the immediate, short-term (<1 year) effects of fire occurring at primarily low to moderate severities within their territories. Other researchers have documented negative impacts of large stand-replacing fires on spotted owl occupancy (Elliot 1985, MacCracken et al. 1996, Gaines et al. 1997). Gaines et al. (1997) reported lower site occupancy and reproduction one year following the Hatchery Complex fires that occurred on the Okanogan and Wenatchee National Forests.

Management efforts during most of the twentieth century to suppress fire may have increased the amount of suitable habitat on the landscape, but simultaneously resulted in a greater risk of habitat loss due to high intensity fire (Agee and Edmunds 1992, Buchanan et al. 1995, Everett et al. 1997, Gaines et al. 1997). On the Okanogan and Wenatchee National Forests, about 40% of the northern spotted owl activity centers occur within the dry forests and mesic forests.

Little is known about the interactions between spotted owls and disturbances created by insects and disease. However, many of the nest sites that have been monitored on the east side of the Cascades occurred within mistletoe brooms and are often associated with abandoned goshawk nests (Buchanan et al. 1995).

Canada Lynx—Subalpine Forest Habitats

The Canada lynx was selected as a focal species because of its association with subalpine fir forests (Aubry et al. 1999), it was used as a focal species in the Columbia Basin Assessment (Wisdom et al. 2000), and it has been recommended for use as a focal species in forest planning (USDA FS n.d.).

Canada lynx occur in most boreal forest habitats in North America, including the upper elevation coniferous forests of the Cascade Range (Aubry et al. 1999). On the Okanogan and Wenatchee National Forests, suitable lynx habitats occur within the subalpine fir forested plant associations. Lynx habitat components include foraging and denning. Foraging habitat is composed primarily of relatively young stands that have high stem densities or older forests with a substantial understory of shrubs and young conifer trees that support populations of snowshoe hares (Ruediger et al. 2000). Denning habitat may be found in either older mature forest of conifer or mixed conifer, or in regenerating stands (>20 years since disturbance) with coarse woody debris (Ruediger et al. 2000). Lynx habitat that is currently in unsuitable condition includes areas that are in very early successional stages as a result of recent fires or vegetation management, and vegetation has not sufficiently developed to support snowshoe hare populations during all seasons (Ruediger et al. 2000).

The population center for lynx within the assessment area occurs within the Meadows Area located on the Methow Valley and Tonasket Ranger Districts (McKelvey et al. 1999, Stinson 2001). It includes terrain and forest types that provide a large contiguous block of suitable lynx habitat. Suitable lynx habitat elsewhere on the Okanogan and Wenatchee National Forests generally occurs in small blocks and is naturally fragmented by steep terrain and non-subalpine fir forest types that do not provide suitable habitat. An exception to this occurs on the national forest and state wildlife lands surrounding Table Mountain on the Cle Elum Ranger District. Geological and vegetation conditions here provide a relatively large block of subalpine forests. However, it is unknown if lynx currently occupy this area.

Fire, wind, insects, and disease were historically important in maintaining the mosaic of forest successional stages that provide habitat for both snowshoe hare and lynx (Fox 1978, Bailey et al. 1986, Quinn and Thompson 1987, Koehler and Brittell 1990, Poole et al. 1996, Slough and Mowat 1996). For the first few years following a fire lynx use appears to decline (Fox 1978). However, about 15 to 30 years following fire peak use by snowshoe hares occurs. Snowshoe hares are the primary prey for lynx (Ruediger et al. 2000). Hare populations again decrease as the forest canopy develops and shades out the understory. Forest gap development processes, such as large blowdowns, insect infestations, and outbreaks of disease, produce similar habitat conditions (Agee 1999).

Historically, lynx habitat in the Cascade Mountains was maintained by infrequent (70-150 years) stand-replacing fire regimes (Agee 1999). The effects of fire exclusion on lynx habitat vary, but, in general, fire exclusion in areas of long fire return intervals probably has not had much impact (Habeck 1985, Agee 1993).

V. Findings

This section describes what the FHA team found in regard to forest vegetation, insect and disease conditions, fire potential, and wildlife. This section also discusses how conditions are likely to change over the short and long term.

Vegetation

During the twentieth century the proportion of total conifer stocking composed of later seral species, such as Douglas-fir and grand fir, has increased substantially forest wide, while the proportion of early seral ponderosa pine has declined. Everett et al. (1997) sampled 48 spotted owl nest sites on moist and dry sites on the Wenatchee and Okanogan National Forests. They found that “historical forest structure had significantly lower tree densities . . . and had reduced representation of shade tolerant species.” Schellhaas and Ohlson (n.d.) reported that since 1900 average stocking of ponderosa pine and Douglas-fir in dry and mesic forests has significantly increased on the Tonasket and Methow Valley Ranger Districts. Since 1900, species composition changed markedly while the proportion of Douglas-fir increased significantly relative to ponderosa pine, while the average stocking of western larch declined. Suckley and Cooper (1860) reported open forest conditions from the east slopes of Mount Adams, to the Okanogan River, to Fort Colville. They reported open forest beginning about 2,200 feet along the Yakima River and a “scattered belt of forest” near 5,750 feet “in which the larch appeared, of great size, and about equal in abundance with the pines . . . with these were a few scattered spruces [Douglas-fir and grand fir].” They described the lower elevation forests from Mount Adams north to Fort Okanogan as being sufficiently open that “a wagon could be drawn though them without difficulty.” Compared to conditions that existed at the turn of the twentieth century, Camp (1999) reported significant increases in the abundance and dominance of true fir and Douglas-fir species, and corresponding reductions of ponderosa pine abundance within the Swauk Late Successional Reserve near Blewett Pass.

With a few exceptions, during the past century forest tree cover has become significantly more homogeneous in all forest types on the Okanogan and Wenatchee National Forests. Agee (1998) found that as fire regimes have transitioned from low severity to mixed severity, and from mixed to high severity patch sizes have increased. He noted that forested openings once common have decreased in size and that the edge between mature and old forest has been blurred as forests have become more dense and multi-layered. In the absence of management or wildfire all forest types are likely to become increasingly dense. This is especially evident in dry and mesic forests.

In the dry and mesic forest types, early seral species, such as ponderosa pine and western larch, have a competitive disadvantage with shade tolerant Douglas-fir and grand fir on undisturbed sites. Shade tolerant species are expected to increase their domination of dry and mesic forests. At the same time, it is likely that forests will be more homogeneous. Individual stands will likely show increasingly strong multiple canopy characteristics as individual trees are killed by root disease, insects, or competition effects. Later seral species, such as Douglas-fir and grand fir that can establish and grow in low light conditions, will exclude pine and larch from the understory. Early seral conifer species will establish and thrive only where there are canopy-reducing disturbances, such as from thinnings, non-lethal and mixed severity fire, or lethal fire.

In the absence of low intensity disturbance that reduces tree stocking, such as from non-lethal fire or mechanical thinning, forests that established after a lethal fire or following regeneration harvesting will experience rapid canopy closure. Eventually conifers will attain sufficient size to become susceptible to bark beetles or to other gap-forming disturbances.

Open forest canopies created by thinning or regeneration cutting are transitory. Crown closure occurs within about twenty years of disturbance on most forest sites on the Okanogan and Wenatchee National Forests (Appendix C). In the absence of continued disturbances that control conifer stocking, we expect multiple canopy forest to rapidly recur on most dry, mesic, and moist forest types as conifer seedlings establish following mechanical thinning or the application of prescribed fire.

North Zone

The distribution of forest vegetation types in the North Zone is shown in Figure F. Dry and mesic forest is associated with lower elevation valleys and hill slopes. Nearly five hundred thousand acres of dry and mesic forest is dense (Table 2). Acreages have not been adjusted to account for ingrowth or for large fires and silvicultural activities that have occurred since the late 1990s.

Forest type and density	Acres
Dry not dense	102,924
Dry dense	279,095
Mesic not dense	58,633
Mesic dense	206,840
Moist small dense	246,201
Moist small not dense	77,767
Moist large	256,210
Cold dry	50,102
Total forested acres	1,277,772

Table 2. Acreage by forest type and density, North Zone

Forest vegetation is much more dense in the dry and mesic forest types compared to pre-settlement conditions. In addition, there is a strong tendency toward multiple canopy structure, with small, medium, and larger trees all occurring on the same acre. Data from stand examinations and from forest inventory plots taken since the early 1990s indicate that forest densities exceeding 120 square feet of basal area with over 300 trees per acre are common in dry and mesic forests. The Colville Confederated Tribes (1997) used 1908 public land survey records from the Colville Indian Agency, early accounts of Bureau of Indian Affairs agents, and oral histories compiled from Tribal elders to estimate tree size and stocking in the early 1900s. They reported that in the early 1900s the average density of mid and lower elevation forests on the Colville Indian Reservation was fewer than 40 trees per acre, with less than 40 square feet of basal area per acre. Forest structure on drier sites tended to have one, or at most two, canopies. The description of forest conditions is very consistent with reports from railroad surveys for the east slope of the Cascades and north central

Washington conducted in the mid-nineteenth century (Suckley and Cooper 1860). The railroad surveys discuss forest structure and density from the east slope of Mount Adams to Fort Okanogan, and on to Fort Colville. Because of similar forest composition, climatic conditions, and Native American burning practices, it is likely that the pre-settlement forest densities on the Tonasket and Methow Valley Ranger Districts were quite similar.

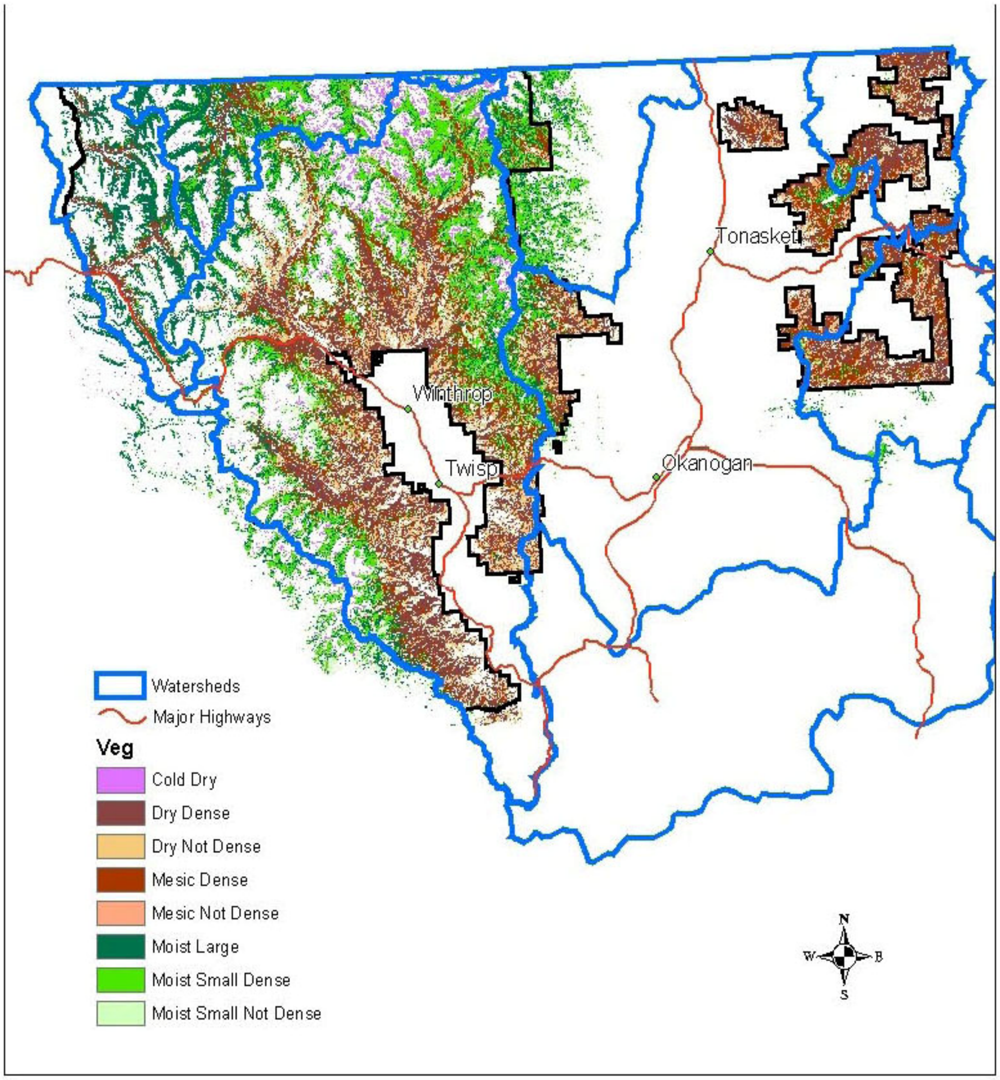


Figure F. Forest vegetation types, North Zone

Forests will continue to become more dense and develop multiple canopy characteristics in the absence of disturbance by management or from wildfire.

Central Zone

Dry and mesic forest is associated with mid and lower elevation valleys and hill slopes. About 300,000 acres of dry and mesic forest is dense (Table 3). Acreages have not been adjusted to account for ingrowth or for large fires and silvicultural activities that have occurred since the late 1990s.

Forest type	Acres
Dry not dense	345,484
Dry dense	239,512
Mesic not dense	32,349
Mesic small dense	8,215
Mesic large dense	50,230
Moist small dense	17,448
Moist small not dense	59,759
Moist large	310,136
Total forested	1,063,133

Table 3. Acreage by forest type and density, Central Zone

Since the 1960s, much of the Chelan and Entiat Ranger Districts and a large area near Leavenworth and Cashmere on the Wenatchee River Ranger District burned in stand-replacing wildfires. During the 1960s, 1970s, 1980s, and early 1990s it was common to salvage fire-killed timber. This removed substantial amounts of biomass and fuel from thousands of acres. Little or no post-fire salvage has occurred from fires that burned after the mid-1990s. On dry and mesic sites, post-fire reforestation has successfully established well-stocked, even-aged seedling, sapling, and pole size forests composed primarily of ponderosa pine. On cooler and moister sites post-fire natural regeneration has created dense stands of sapling and small pole size lodgepole pine and Douglas-fir, and true fir. Large live trees are generally absent from much of the fire impacted landscape. The distribution of forest types is shown in Figure G.

For example, Harrod et al. (1999) found that the pre-settlement stand structure of dry forests consisted of 45-70 ft^2 per acre of basal area and average densities of 20 trees per acre, mostly of large diameters. Suckley and Cooper (1860) reported large widely spaced trees in lower elevation forests all along the Columbia from the east slope of Mount Adams to Fort Okanogan. Current basal areas are over 120 ft^2 per acre and tree densities as high as 1,000 trees per acre are common. Most of the conifers are trees with a breast height diameter less than 12 inches.

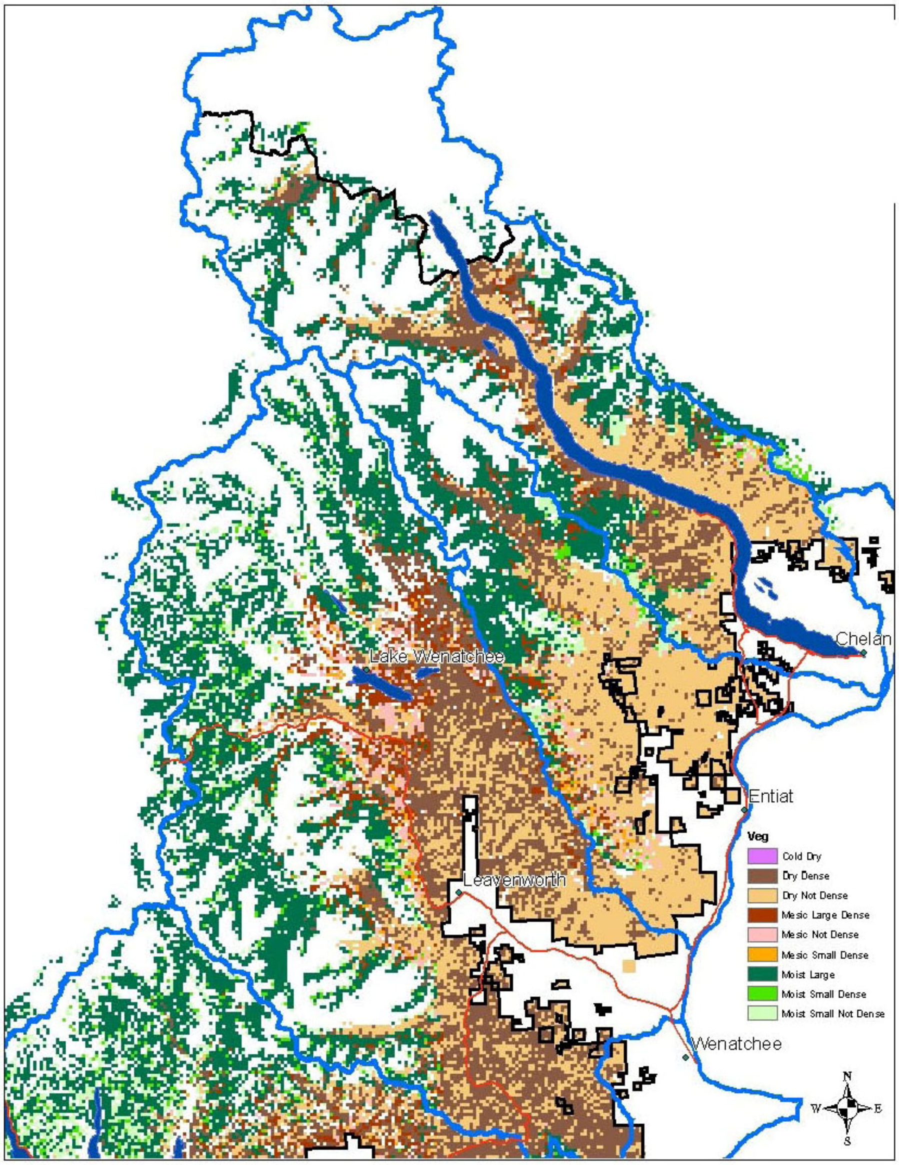


Figure G. Forest vegetation types, Central Zone

Conifer forests established after the 1960s and 1970s wildfires are rapidly achieving crown closure. Many stands that were planted after the 1960s fires are already large enough to be susceptible to bark beetles. Stands planted after 1970 will be susceptible within 10 to 15 years. On remnant forest that escaped the lethal crown fires of the last thirty years, stands have a well-developed multiple canopy structure. Where Douglas-fir or grand fir are present in the understory they will aggressively complete with ponderosa pine, and, in most cases, will replace pine as the dominant species.

South Zone

Dry and mesic forest occurs at mid and lower elevations. Over 200,000 acres of dry and mesic forest is dense (see Table 4).

Forest type	Acres
Dry not dense	65,847
Dry dense	183,168
Mesic not dense	20,771
Mesic small dense	9,718
Mesic large dense	20,771
Moist small dense	38,128
Moist small not dense	92,447
Moist large	441,151
Total forested	911,598

Table 4. Acreage by forest type and density, South Zone

Acreages shown in Table 4 have not been adjusted to account for ingrowth or silvicultural activities that have occurred since the late 1990s.

The Cle Elum and Naches Ranger Districts had several thousands of acres of selective cutting and other partial removal cuts between the 1950s and early 1980s. Large, economically valuable ponderosa pine, Douglas-fir, and western larch were removed, often leaving an understory of grand fir and Douglas-fir. In the late 1980s and early 1990s private lands within the national forest boundary on the Cle Elum Ranger District were heavily harvested by clear cutting and selective harvests. The Forest Service has acquired many of the private lands. Harvest activities and the absence of fire have resulted in a major change in species composition. Former pine and larch forests are often dominated by grand fir and Douglas-fir. Many of the recently acquired selectively harvested lands are heavily diseased, and substantial amounts of untreated logging slash remain in many stands.

Unlike other portions of the Okanogan and Wenatchee National Forests, Ranger Districts in the South Zone experienced relatively little wildfire activity in the later half of the twentieth century. Conifer stocking has been increasing on dry and mesic sites. Relatively low amounts of stand management on the Cle Elum Ranger District since the mid-1980s have resulted in contiguous, dense multiple canopy forest within the WUI. Harvested stands acquired in recent land exchanges on the Cle Elum Ranger District have a heavy component of shrubs where natural regeneration by Douglas-fir and grand fir is likely to dominate the lower canopy to the exclusion of ponderosa pine. Over time these stands will develop an increasingly multiple canopy structure. The distribution of forest vegetation in the South Zone is shown in Figure H.

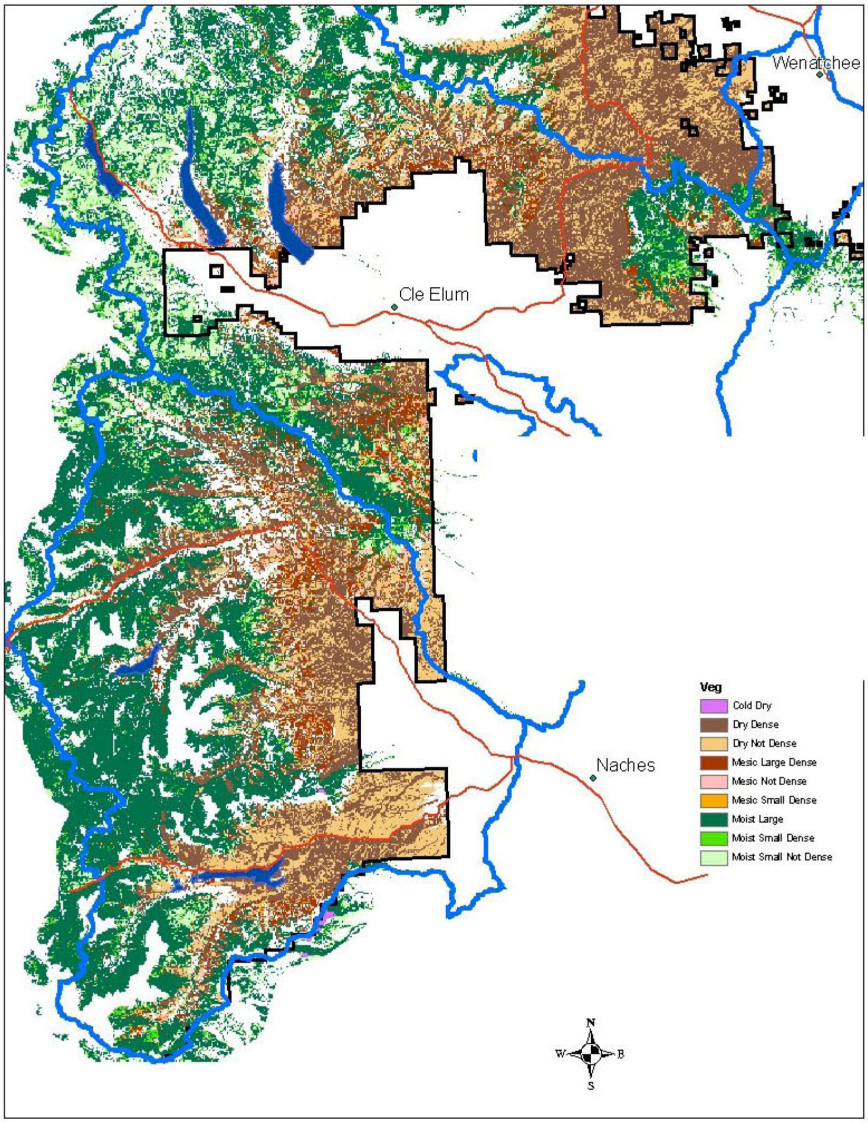


Figure H. Forest vegetation types, South Zone

Insects and Diseases

Many types of insects feed on trees. Bark beetles generally kill trees outright. Defoliators can also kill trees, or can leave trees weakened and susceptible to bark beetles. Aerial surveys conducted since 1980 show areas of extensive mortality caused by bark beetles and by repeated defoliation from western spruce budworm. Most of this has been concentrated in the North Zone (Figure I).

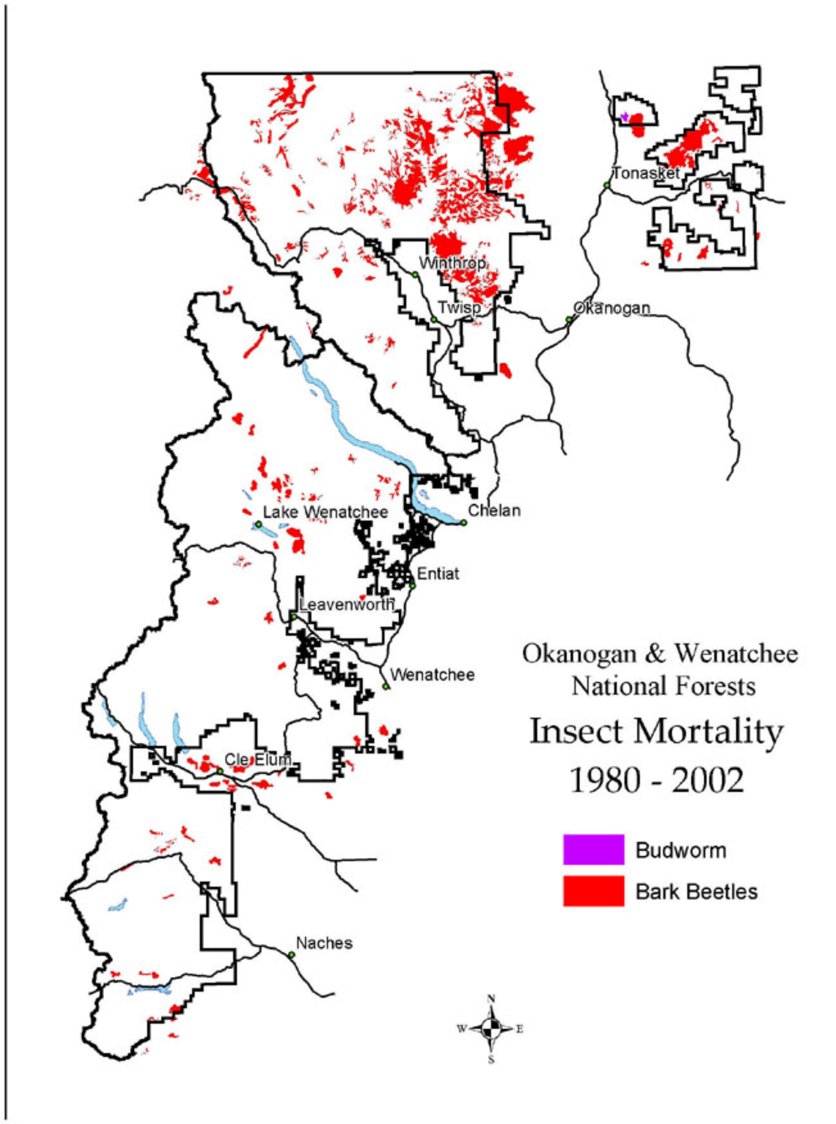


Figure I. Tree mortality from bark beetles and defoliator insects, 1980-2002, forest-wide (Okanogan and Wenatchee National Forests)

Bark beetles have been most active in spruce and lodgepole pine in the moist vegetation types (Figure J). About one million trees on 187,000 acres have been killed by either spruce beetles or mountain pine beetles in this forest type. This is likely to continue until all susceptible host trees have been killed.

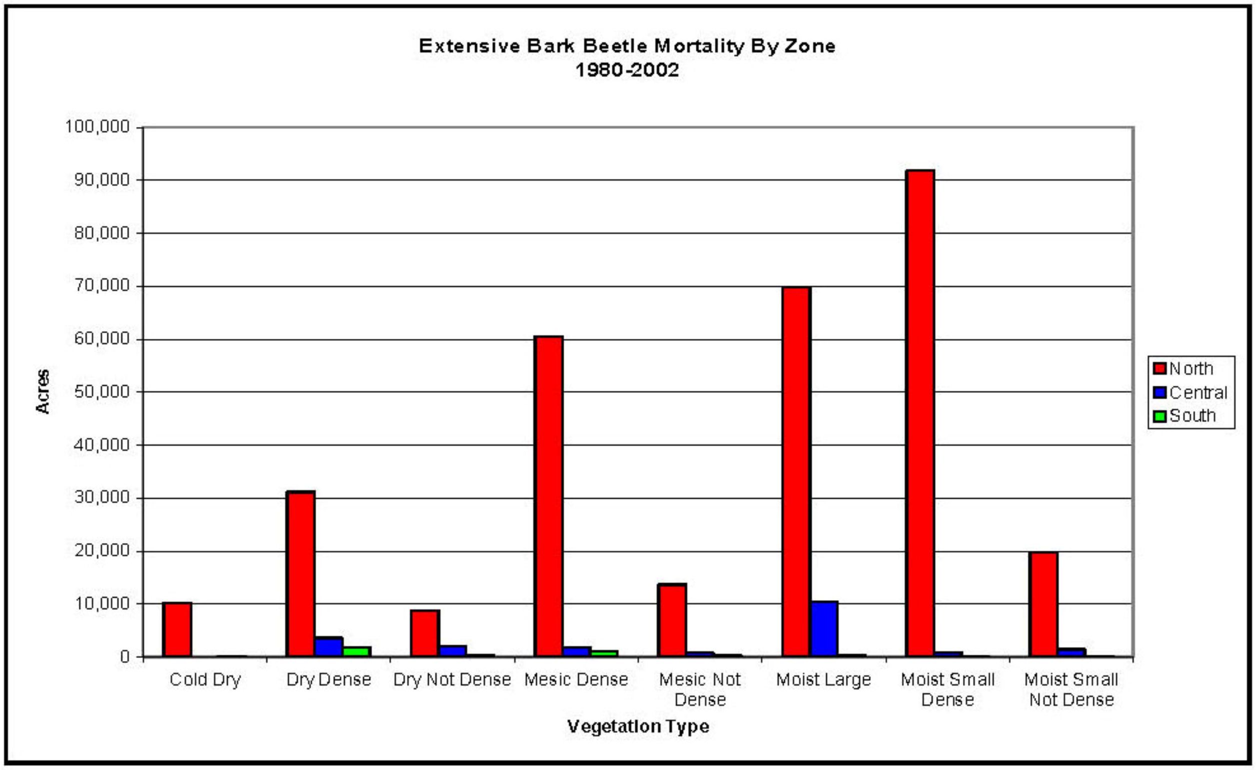


Figure J. Extensive bark beetle-caused mortality by forest type, 1980-2002

Dense, multiple-canopy dry and mesic forests on all Ranger Districts are capable of supporting defoliator outbreaks. Past defoliator outbreaks have often been suppressed with various insecticides which may reduce existing insect populations below outbreak levels. In some cases, such as the 2001 suppression effort against Douglas-fir tussock moth, the population may crash. Direct suppression is not an effective long-term strategy because it does not correct the underlying problem of historically unprecedented large numbers of host trees on dry or mesic sites.

Douglas-fir dwarf mistletoe is abundant in the dry and mesic forest types. It becomes less frequent in the moist forest type because Douglas-fir diminishes in abundance. Infection of Douglas-fir results in growth reductions, distorted growths, top-killing, and premature tree death. Douglas-fir dwarf mistletoe is the most lethal of the mistletoes that occur on the Okanogan and Wenatchee National Forests. Nevertheless, tree killing by this mistletoe is chronic and develops slowly. Concentrations of Douglas-firs killed by dwarf mistletoe tend to be localized.

Because it kills so many trees, larch dwarf mistletoe is a major cause of the decrease of western larch on the Forests. Even though this mistletoe is damaging, the mortality is chronic and develops slowly. Tree killing occurs over the entire range of larch on the Forests, but large concentrations of larches killed by mistletoe do not exist.

Dwarf mistletoe infestations develop and spread slowly in trees and stands. One result of fire exclusion and selective harvesting is an increase in Douglas-fir dwarf mistletoe over the last century. The trend is for continued increases in Douglas-fir dwarf mistletoe.

The portion of the Tonasket Ranger District east of the Okanogan River has the most intense Douglas-fir dwarf mistletoe infestations. However, on every Ranger District about half of the Douglas-fir stands are infested.

Spread and intensification of Douglas-fir dwarf mistletoe within stands of trees can be slowed and in some cases prevented. Killing or removing large infected trees to prevent infections in small, developing Douglas-firs can effectively reduce disease levels in understory trees and reduce overall infection within infected stands.

Forest wide, the proportion of acres with larch that are infected with dwarf mistletoe has probably not increased over the last century and will not likely increase greatly in the future. However, there are many thousands of acres of western larch stands on the Okanogan and Wenatchee National Forests with scattered residual infected larch over developing larch regeneration. Smith (1966) determined that larch dwarf mistletoe plants in a single infected western larch could cast dwarf mistletoe seeds over 2,200 ft^2, infecting larch seedlings located within 30 feet of the diseased tree. Smith calculated that fewer than 20 infected overstory trees per acre could disseminate dwarf mistletoe seeds over the entire acre. Infected larch regeneration infected from diseased overstory trees will experience growth loss and premature death from increasingly severe dwarf mistletoe infections (Wicker and Wells, 1983) (Wicker and Hawksworth, 1988). Much of the projected damage from larch dwarf mistletoe can be prevented by removing infected overstory larch before larch understory trees become infected.

According to several project evaluations and several years of observation by zone pathologists, the greatest increases in root disease infection and resultant tree killing have occurred on the Naches, Cle Elum, and Wenatchee River Ranger Districts. Laminated root rot can be found in many moist Douglas-fir and grand fir stands where it causes chronic but rarely acute mortality. Annosus root and butt rot is common in grand fir stands with a history of tree cutting but the disease does not kill many trees, instead it causes internal stain and decay of the stems. Root diseases are not rapidly causing concentrations of dead trees over large areas. The trend is toward more root disease infection and more tree killing. Selection harvests and thinning that retain Douglas-fir and grand fir are likely to result in a slow intensification of root diseases where they are already present.

White pine blister rust continues to kill five-needle pines but the mortality is chronic. Because there are very few large stands of these pines, tree killing is scattered, seldom creating concentrations of dead trees. The trend for this disease is for continued chronic mortality. Increases are not anticipated.

North Zone

The dramatic activity of bark beetles of the genus *Dendroctonus* on the Methow Valley and Tonasket Ranger Districts over the last 18 years has been a major forest disturbance. The principal tree species affected are lodgepole pine, Englemann spruce, and Douglas-fir. Since 1985 there has been a continuous outbreak of pine beetles in the Meadows area, a large forested area that lies between the Methow, Similkameen, and Okanogan Watersheds. The Meadows area is bounded on the north by the Pasayten Wilderness and on the south by Bear Creek. In the late 1990s a spruce beetle outbreak began killing a substantial numbers of trees. The combined pine and spruce outbreaks have resulted in about 187,000 acres of dead lodgepole pine and Engelmann spruce in this mostly unroaded area. This is the largest continuous expanse of dead trees on the Okanogan and Wenatchee National Forests. It is primarily in the moist and cold dry forest types (Figure F Figure K). In the Similkameen Watershed south of the Canadian border about 40% of the area has been affected by bark beetles. Affected portions of the watershed are unroaded or entirely within wilderness. Data for the Canadian side is not available.

Mountain pine beetle and western pine beetle have killed substantial numbers of lodgepole and ponderosa pine trees on 36,000 contiguous acres in the Eightmile and Falls Creek drainages of the Methow Watershed. The outbreak has been continuous since 1988. Overall, about 20% of the Methow Watershed has been affected by extensive bark beetle activity. In the Mount Bonaparte area, bark beetles have affected 25,000 acres between the Okanogan and the Kettle River Watersheds. The outbreak began in 1987. Extensive mortality of pines on dry sites will accelerate the transition to Douglas-fir, thereby increasing the likelihood of a spruce budworm outbreak (Wilson et al. 1998).

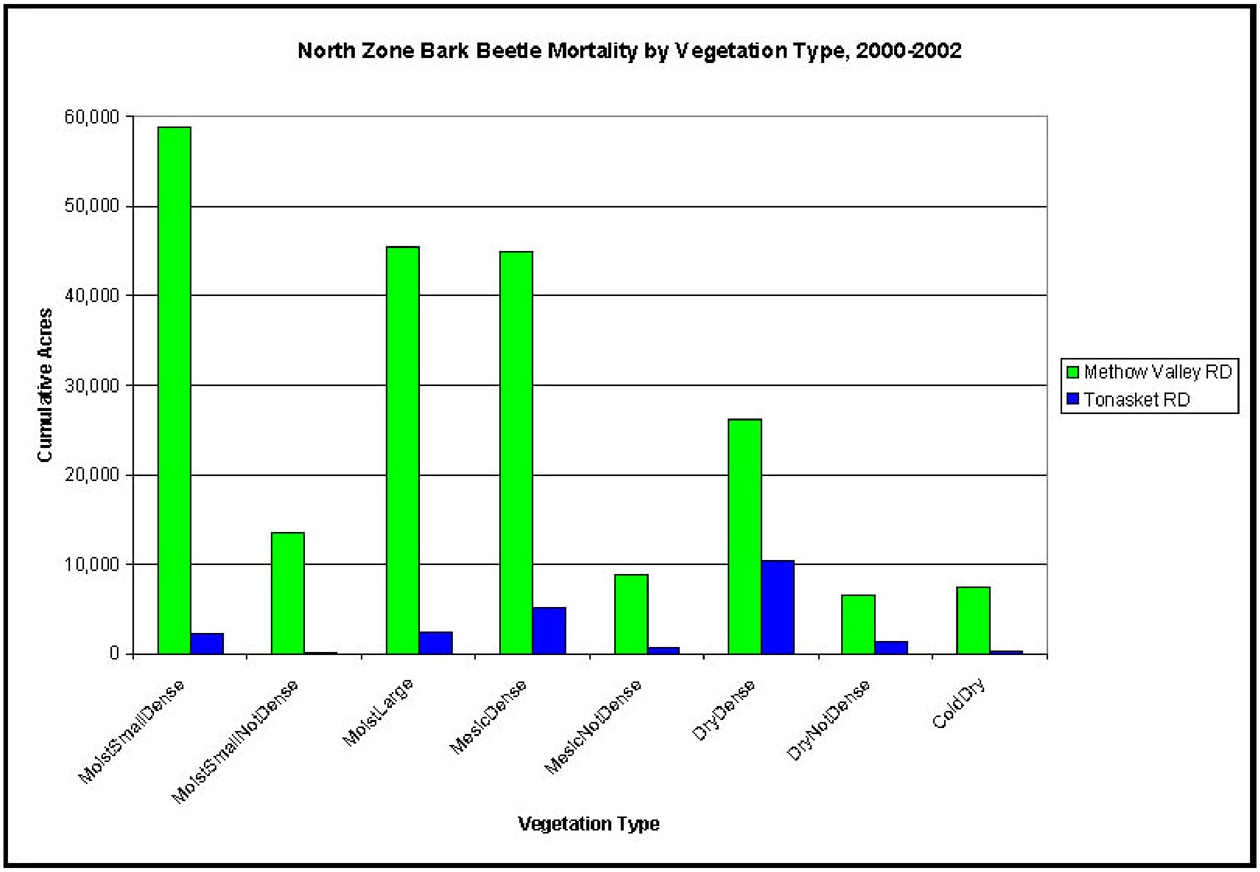


Figure K. Acres of trees killed by bark beetles, 2000-2002, North Zone

About 20,000 acres in the Ross Lake Watershed have been affected by mountain pine beetles in lodgepole pine. In addition to National Forest lands, adjacent National Park lands have also been affected. This area was first identified in 1990; the outbreak continues.

Extensive Douglas-fir beetle activity has been recorded intermittently in the San Poil Watershed on the Okanogan and Wenatchee National Forests, the adjacent Colville National Forest, and on adjoining Tribal and private lands. Most of this occurred in the 1990s. The population of Douglas-fir beetles on the Colville National Forest and the northeastern corner of the Tonasket Ranger District increased dramatically in the late 1990s following blowdown from a 1996-1997 winter storm. This increased population has affected stands in the Kettle River and San Poil Watersheds.

Recent bark beetle activity on Ranger Districts in the North Zone is shown in Figure L. During the next five years there will be continued epidemic mortality of Engelmann spruce in the Meadows area. Most of the Engelmann spruce larger than eight inches in diameter will be killed. Over the next ten years, lodgepole pines larger than five inches in diameter will continue to be killed by mountain pine beetles.

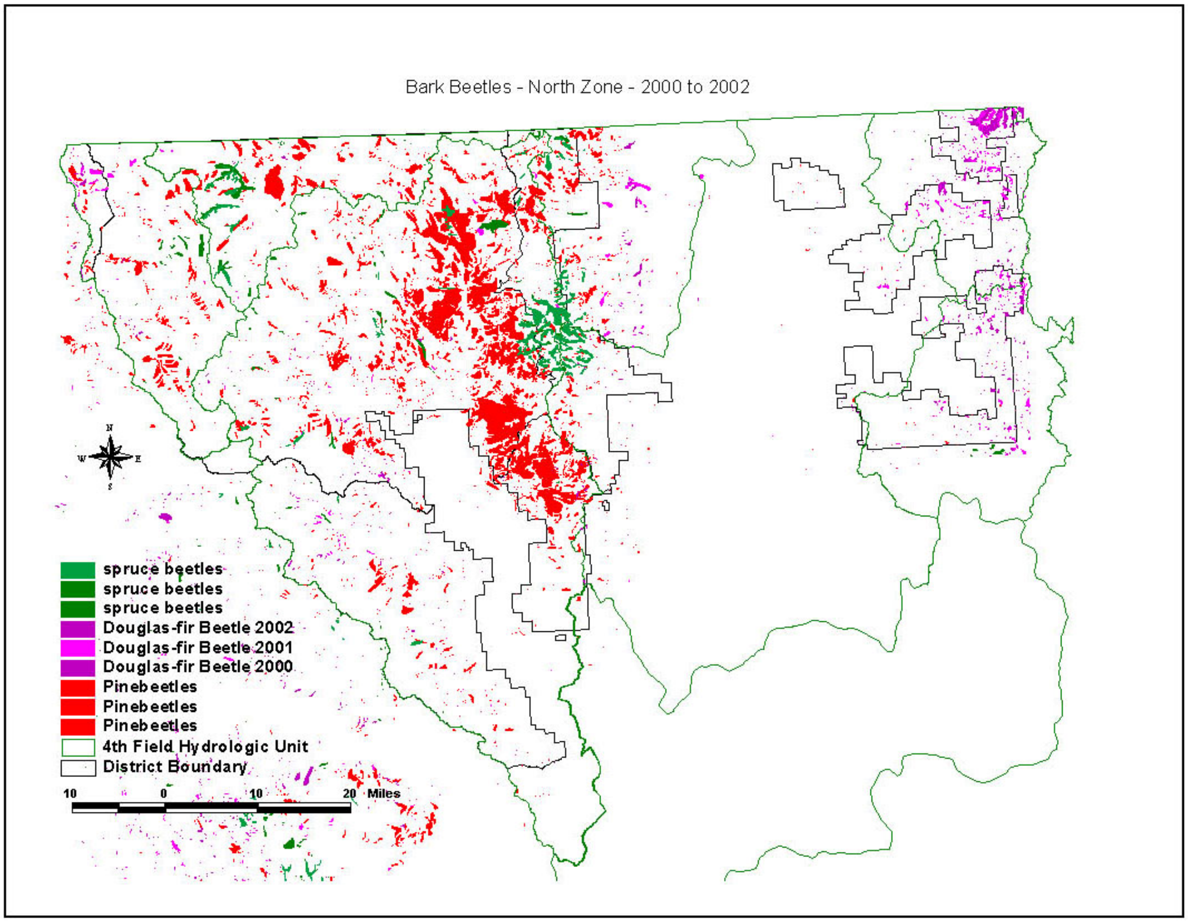


Figure L. Bark beetle activity, 2000-2002, North Zone

Western pine and mountain pine beetles will continue to cause mortality in dense lodgepole and ponderosa pine stands throughout the Methow, Ross Lake, and Similkameen Watersheds. Any pine stands of these species with more than 90 square feet of basal area per acre are susceptible to bark beetle attack.

In the Okanogan Watershed around Mount Hull, 860 acres were severely defoliated by spruce budworm in the early 1990s. The outbreak caused substantial mortality of understory trees. This is the only extensive mortality caused by budworm on the Okanogan and Wenatchee National Forests to have occurred in recent years.

Multi-storied stands of Douglas-fir on dry sites have been increasing in density and total acreage in the Kettle River, San Poil, Okanogan, Similkameen, and Methow Watersheds. These stands provide prime habitat for western spruce budworm. Budworm has defoliated Douglas-fir forests in these watersheds in the past, and in the next 10-20 years will probably be a significant defoliator. Light budworm defoliation is visible in many portions of the Methow Watershed in 2003, and adult moths appeared numerous.

Central Zone

Bark beetle activity in the Ranger Districts in the Central Zone has been most visible on the divide between the Entiat and Wenatchee Watersheds on the Entiat and Wenatchee River Ranger Districts. Here, over 8,000 acres of dry forest type have been affected within the last five years. Mountain pine beetle-caused mortality was mapped on over 1,100 acres in the Icicle Ridge area in 2002. Several thousand acres of recent mountain pine beetle activity in higher elevation forests were observed in the northeastern portion of the Chelan Watershed. Douglas-fir beetles have caused continued scattered mortality of large Douglas-firs over the last three years (see Figure M). Trees in stands that were planted after the 1970s wildfires are growing in over-dense conditions. They are approaching, and in some cases have attained, diameters that will make them susceptible to bark beetles. If there is no change in the dense stocking in these stands (Sartwell and Stevens 1975), we can expect substantial mountain pine beetle-caused mortality to begin in the next decade.

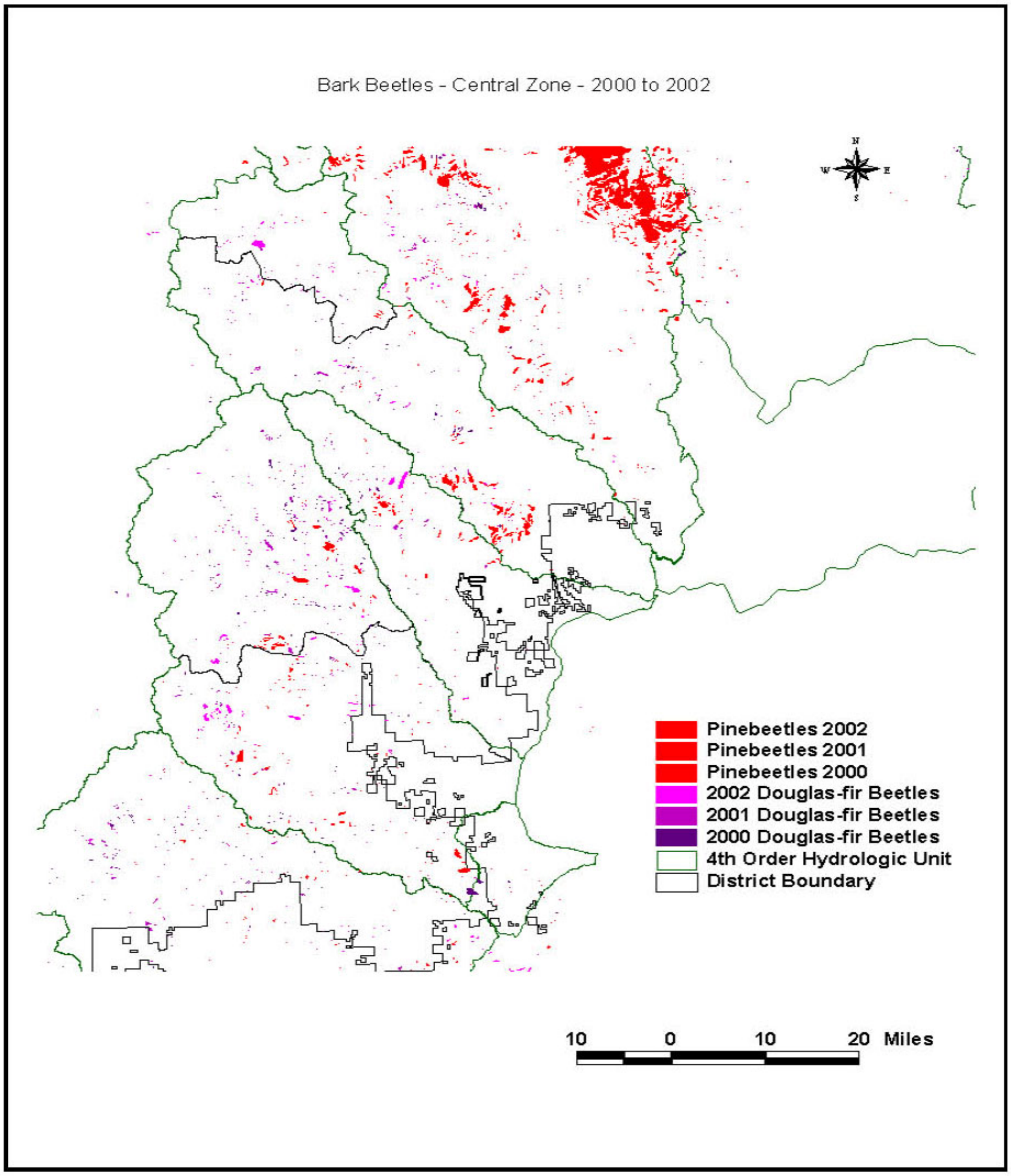


Figure M. Bark beetle activity, 2000-2002, Central Zone

The current level of insect activity in the Central Zone Ranger Districts is expected to continue over the next five to ten years. Douglas-fir beetle activity could increase on the Wenatchee River Ranger District and in remnant mesic forest stands on the Chelan and Entiat Ranger Districts if disturbances such as fire or blowdown provide weakened trees in which the population can build up. Mountain pine beetles will continue to kill lodgepole and ponderosa pines in the Chelan Watershed. The highest mortality will be in overstocked stands with average diameters of five inches or larger.

South Zone

Though the South Zone Ranger Districts have had considerable bark beetle and defoliator activity in the last three years, this has resulted in relatively limited tree mortality.

Private lands in the Upper Yakima Watershed have experienced some bark beetle-caused mortality. In the recent past the Lower Yakima Watershed has had several concentrated areas of bark beetle activity, totaling several thousand acres. Most of this has been on the south boundary and on adjacent Yakama Indian Nation land (see Figure N).

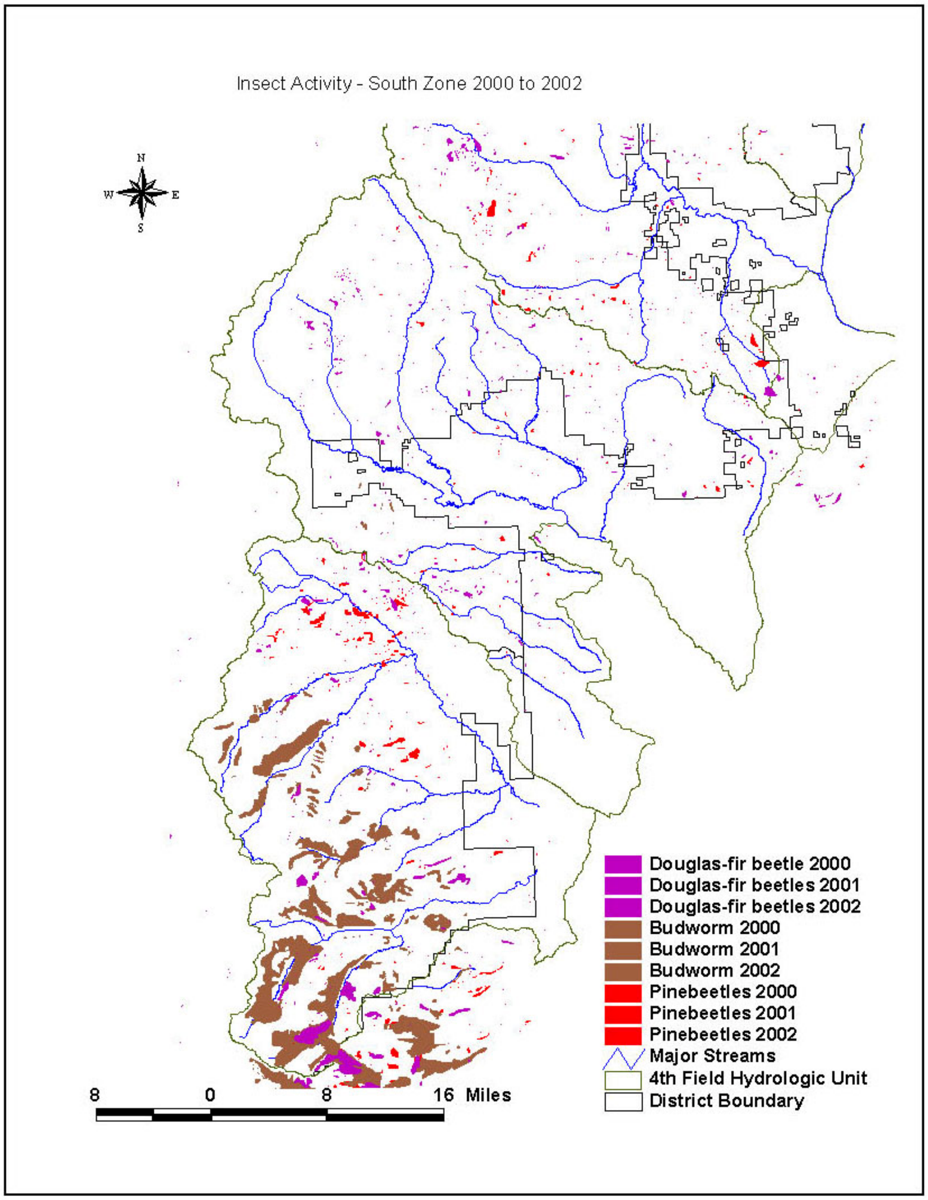


Figure N. Insect activity, 2000-2002, South Zone

Aerial surveys of the Okanogan and Wenatchee National Forests annually report tree mortality from fir engraver. Before 2003, tree mortality caused by this insect was scattered with relatively few acres affected. Most fir engraver attacks were associated with root disease. However, in 2003 a significant increase in fir engraver activity was observed. On Ranger Districts in the Central and South Zones, acreage with at least one tree per acre killed increased by 879% between 2002 and 2003. In 2002 a total of 3,123 acres with fir engraver-caused mortality were observed. In 2003 the area affected increased to 27,457 acres. The most extensive areas of mortality were mapped on the Cle Elum and the Naches Ranger Districts. Increased fir engraver activity resulted from the combined effects of four years of drought and five years of moderate to severe defoliation by western spruce budworm. Elevated levels of mortality are expected to continue as long as extensive areas of true fir continue to be defoliated. Defoliation and associated fir engraver-caused mortality will probably continue for several years.

For the past several years defoliation has occurred from a spruce budworm outbreak (Figure N). This has resulted in some direct mortality, top killing, reductions in tree growth, and increased activity of Douglas-fir beetles. Extensive defoliator-caused mortality has not yet been observed from defoliators, primarily because several years of repeated foliage loss is necessary to kill trees. In 1999, budworm defoliation in the South Fork Tieton drainage has increased to approx 200,000 miles south of U.S. Highway 410 on the Naches District.

Multi-storied stands of Douglas-fir and grand fir are increasing in density and overall acreage in the Upper and Lower Yakima Watersheds. These stands provide prime habitat for western spruce budworm. Budworm will continue to defoliate Douglas-fir and grand fir in the Upper and Lower Yakima Watersheds over the next five to ten years. This will cause some direct mortality, particularly in small trees. It will also cause growth loss and reduced ability to resist bark beetle attacks. Increasing numbers of large Douglas-fir will be killed by Douglas-fir beetle. Fir engraver damage to grand fir is expected to increase in dry and mesic forest types.

Fire

This section describes the findings for fire and fuels and their effect on forest vegetation on the Okanogan and Wenatchee National Forests. Some general forest-wide findings are followed by specific findings for each of the three zones.

Forest-Wide

The dollar costs of fire suppression have increased significantly over the past decade. During the past ten years the Okanogan and Wenatchee National Forests have spent hundreds of millions of dollars on wildfire suppression and post-wildfire rehabilitation, while spending comparatively little on managing forests to reduce long-term hazard. For example, in fiscal year 2003 more than 69 million dollars was spent on suppressing several large wildfires on over 153,000 acres of national forest land, yet only about five million dollars was invested in mechanical treatments and prescribed burning treatments that would mitigate or reduce the severity of wildfire. Most of these acres were in roadless areas and in wilderness where the values at risk are not high. Although wildfire suppression dollars cannot be directly budgeted to treat fuel, funds spent in 2003 alone on the Okanogan and Wenatchee National Forests could have treated nearly 200,000 acres to reduce high fire severity. This is nearly half of all dense dry and mesic forest located in the wildland urban interface.

The most significant departures from pre-settlement conditions across the Okanogan and Wenatchee National Forests are found in dry and mesic forest types. The departure from pre-settlement conditions is not as great in the moist forest types. Graham et al. (1999) showed that activities designed to modify forest structure and composition and to manage uncharacteristic fuel buildup can substantially reduce the effects of wildfire. There is consensus among fuels managers on the Okanogan and Wenatchee National Forests that effective abatement of fuels will require use of both mechanical treatments and prescribed fire. Several project analyses have shown that many dry and mesic sites have too much fuel to achieve desired outcomes with prescribed fire. Finney (2001, 2003) suggests that management activities designed and located in context of the overall landscape pattern and topography may be an effective tool to modify fire behavior and mitigate fire effects. Recent legislation, such as the Healthy Forest Restoration Act of 2003 and administrative direction in the Healthy Forest Initiative (Office of the President 2002, USDA FS 2003) emphasize fuel management treatments in high-value areas and areas of concentrated human activity. It is likely that the area of wildland urban interface will increase during the next ten years.

In the next 10-20 years, in the absence of substantial increases in acres treated to reduce vegetation density and abate fuels, crown fire potential is likely to remain high in all forest types. The current level of treatment acres in dry and mesic forest types, including thinning, other mechanical treatments, and prescribed fire will not change crown-fire potential at a landscape level (Appendix C). Treatments may, in some circumstances, reduce the potential for crown fires in some local situations. At the current level of treatment, it is unlikely that crown fire potential will be sufficiently reduced to provide significant protection in a majority of acres located in the wildland urban interface. However, it is possible that crown fire potential may decrease as the result of the inevitable trend toward more acres burned by high severity fire. In this case, a reduction in crown fire potential as a result of high severity is not a desirable outcome given that wildlife habitat, water quality, soils, and human health and property will be negatively affected.

The current trend of warming climate (Millar and Woolfenden 1999) is likely to increase the probability of large crown fires on all Ranger Districts and in all forest types.

North Zone

The North Zone has experienced several large fires since the late 1980s. Homes and communities are thoroughly intertwined with dry and mesic forest types. Based on preliminary information, the wildland urban interface in the North Zone includes over 230,000 acres of dense dry and mesic forest type. The area in the wildland urban interface is likely to increase as additional homes are constructed near the national forest boundaries. In the recent past several communities have been threatened by wildfire; several homes have burned and lives have been lost to wildfires. Conditions continue to be favorable for large, severe wildfires on both Ranger Districts (Figure O).

There is a substantial risk that wildfire will burn across forest boundaries onto adjacent ownerships. Prevailing southwesterly winds tend to push fires from west to east, and from southwest to northeast. It is possible that a fire may burn across the Canadian border under conditions of continuous fuels and with southerly winds.

Dry and mesic forest types have departed substantially from pre-settlement disturbance regimes which were characterized by low severity, high frequency fires (Agee 1993, Hessburg et al. 1999).

Historically, the majority of dry forest landscapes were dominated by open, park-like stands of large ponderosa pine (Suckley and Cooper 1860). Contemporary landscapes are mostly dominated by stands of dense small pine and Douglas-fir (Agee 1994).

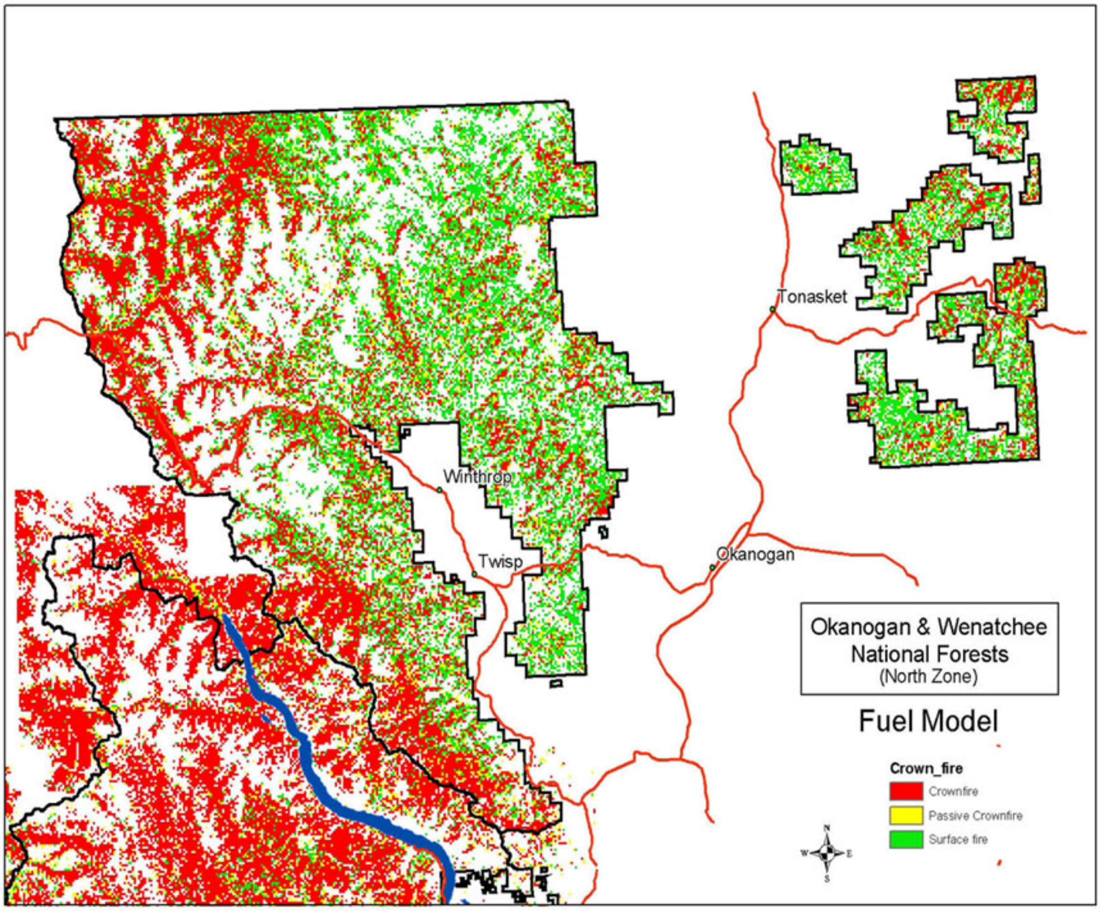


Figure O. Crown and surface fire potential, North Zone

Much of the area analyzed has extensive crown-fire potential (Figure P), but high-risk areas are predominantly within dry and mesic forest types. Dense forest conditions are widespread on the eastern half of the Tonasket Ranger District and the lower elevations of the Methow Valley Ranger District (Figure F, Figure P). Dense dry and mesic forest types have nearly as many acres at high risk of crown fire as of surface fire (Figure P). On the southwestern portion of the Methow Valley Ranger District and the northeast portion of the Tonasket Ranger District the recent incidence of bark beetles within dense dry forest areas is elevating the already high risk of large, severe crown fires.

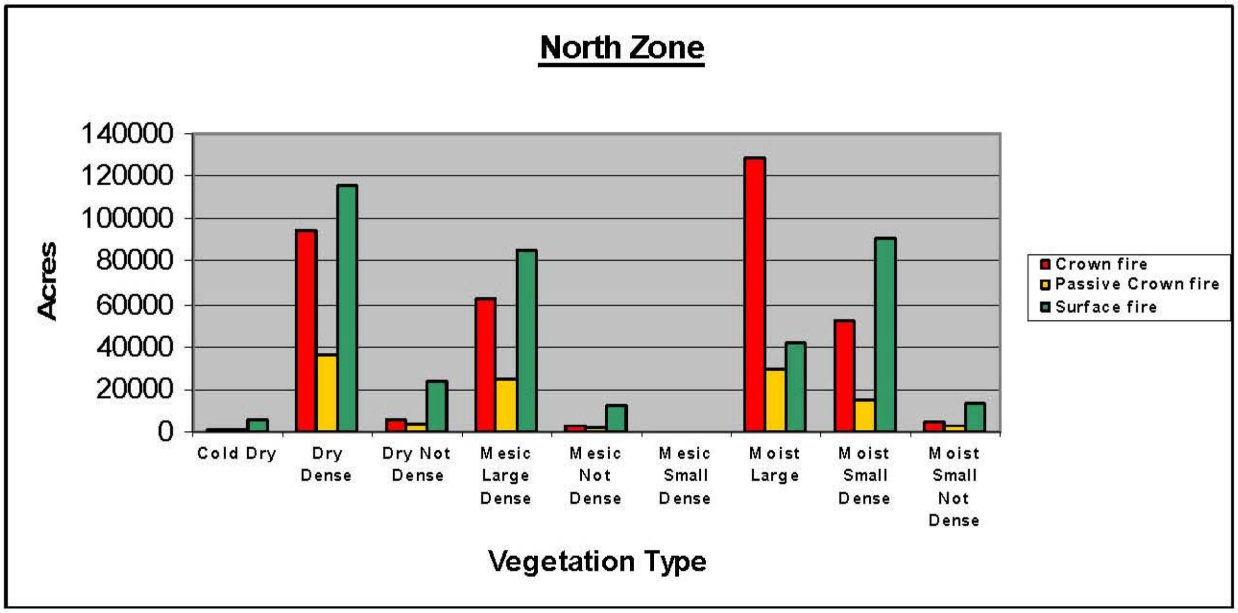


Figure P. Acres at risk of crown and surface fire, by vegetation type and structure, North Zone

Our analysis did not account for recent wildfires, such as the Isabel, Farewell, Needles, Thirtymile, or South Libby Fires, or for recent dry forest restoration activities. The risk of crown fire is currently lowered where these activities have occurred.

Fire starts have been numerous on North Zone Ranger Districts and surrounding ownerships (Figures Q-1, Q-2). Most of the starts are at mid and lower elevations in dry and mesic forest types. Fires are initiated by both natural and human causes. The heavily managed area in the Conconully Basin stands out: it has escaped significant wildfires despite being dry forest type and having a large number of starts. Likewise, the South Summit area has a high proportion of dry and mesic forest type and a high number of starts, yet has not experienced significant acres burned by wildfire. These landscapes, which were thinned extensively in the 1970s and 1980s and in most instances the slash was treated. They have been resistant to large, severe fires because stands are more open, have lower crown densities, and surface fuel loads are relatively low.

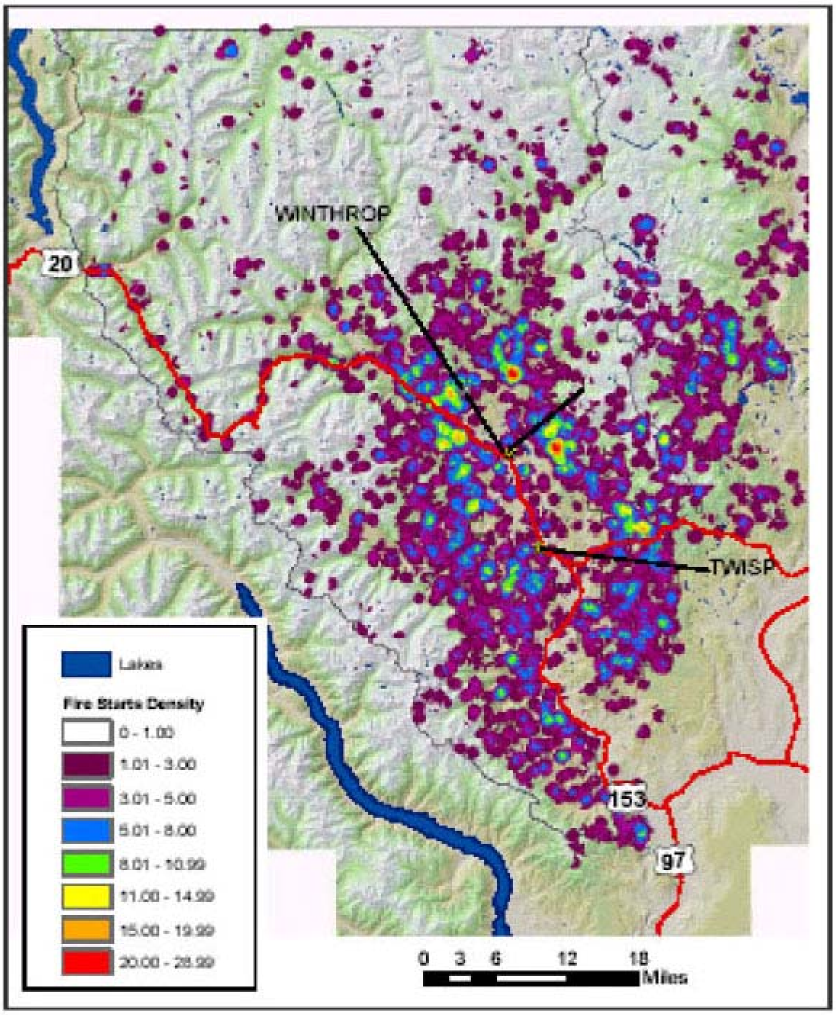


Figure Q-1. Fire start density map displays where the most fire starts have occurred, per square mile, over the last thirty years. Data set from 1970-1999, North Zone, (USDA 2003).

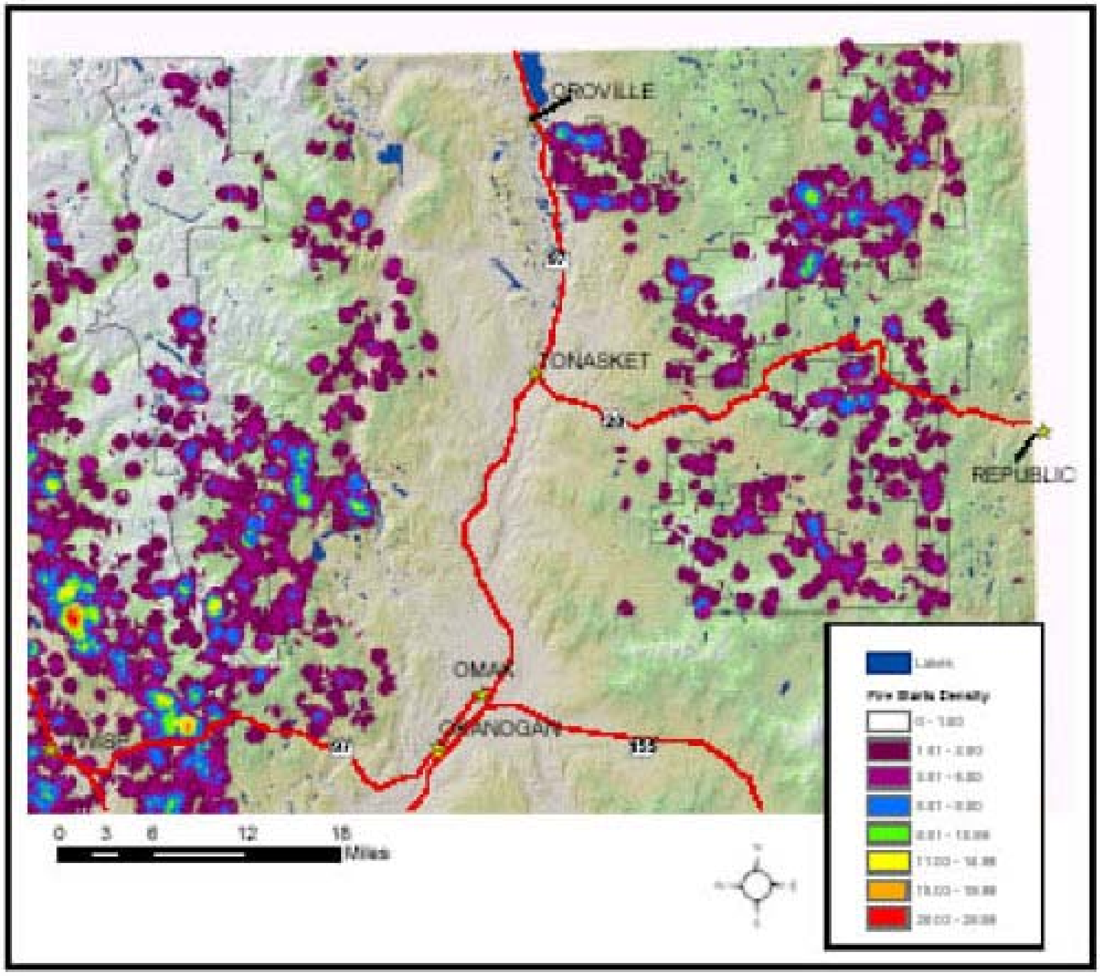


Figure Q-2. Fire start density map displays where the most fire starts have occurred, per square mile, over the last thirty years. Data set from 1970-1999, North Zone, (USDA 2003).

Departures from pre-settlement fire regimes in moist forest environments are generally not as great as changes experienced in dry forest environments (Agee 1994). The Meadows area is located in the high country between the Okanogan, Methow, and Chewuch valleys. It is bounded on the north by the Pasayten Wilderness. The Meadows area is predominantly within the moist and cold dry forest types. Compared to the other parts of the Forest, the Meadows area has experienced a relatively low number of wildfire starts. Weather data from the past thirty years show that, on average, in 1 out of 10 years conditions are conducive to large, crown fire events. When the Meadows area does burn, the substantial amount of contiguous, insect killed lodgepole pine and Englemann spruce will likely lead to large burned areas and severe fire effects.

Fires from dry and mesic forest types may burn upslope into moist forest types. Under severe or extreme conditions, fires burning in moist and cold forest types may burn across forest boundaries on both Ranger Districts, threatening adjacent state, private, or Tribal lands. Fires along the northern boundary of both Ranger Districts have the potential to cross the Canadian border at some locations. Much of the high cost of suppressing the Farewell, Needles, and Isabel Fires of 2003 was associated with efforts to protect private and state lands, and to prevent fire from crossing the border into Canada.

Central Zone

The Central Zone has experienced several very large, severe wildfires in the past thirty years. Much of the Entiat and Chelan Ranger Districts have been burned. Large wildfires have also occurred on the Wenatchee River Ranger District. Wildfires have threatened major communities near all three Ranger Districts. Several homes have also burned within the wildland urban interface and lives have been lost. Based on preliminary information, about 130,000 acres of dense dry and mesic forest type on the Forest are within the wildland urban interface in the Central Zone. Homes and communities are heavily intermingled with forest vegetation. The WUI is not static. It is expected to increase as lands adjacent to the Forest boundaries are further subdivided and developed.

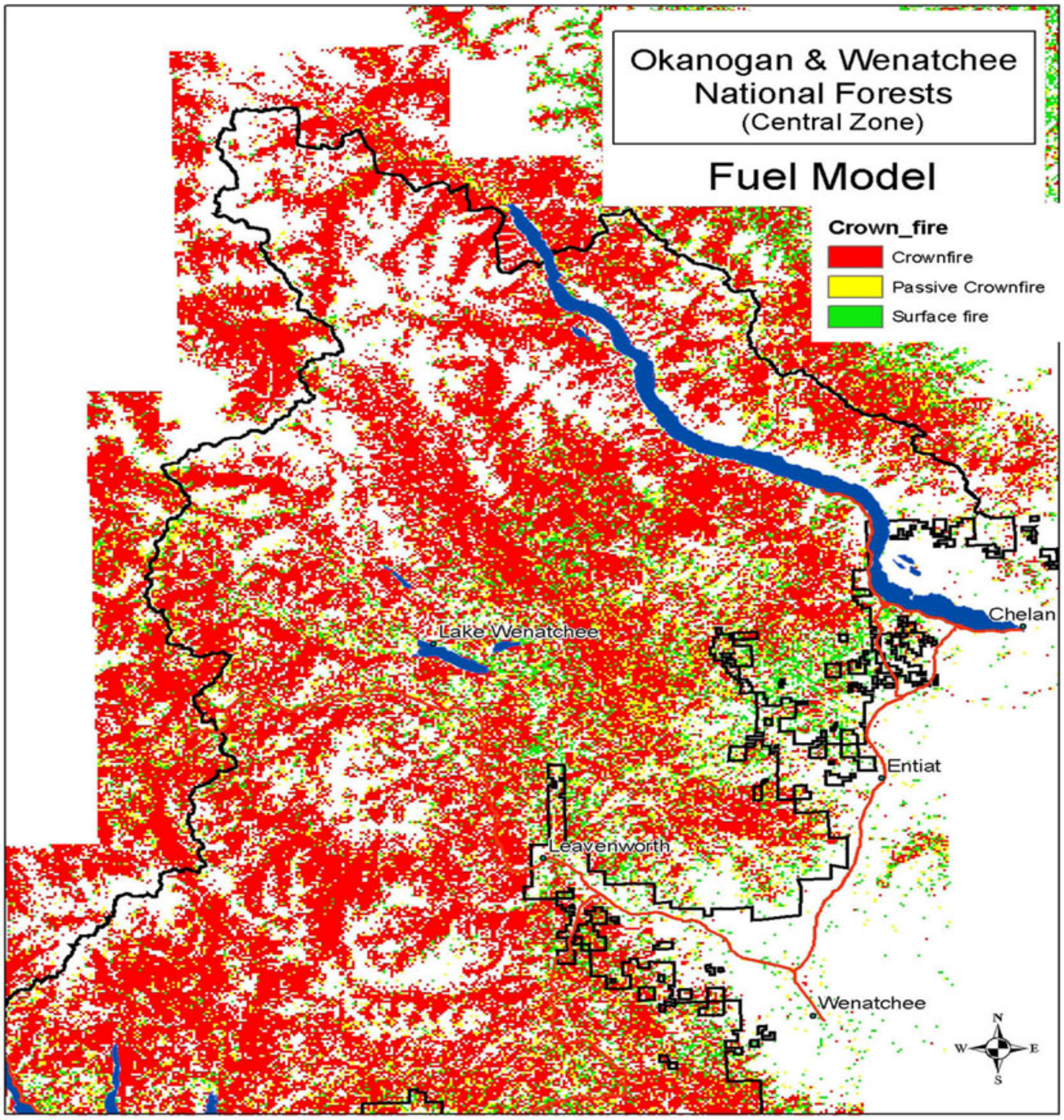


Figure R. Crown and surface fire potential, Central Zone

Dry and mesic forest types in the Central Zone have departed from pre-settlement disturbance regimes, which were characterized by low severity, high frequency fires (Agee 1993, Hessburg et al. 1999). Before settlement the majority of dry forest landscapes was dominated by open, park-like stands of large ponderosa pine (Suckley and Cooper 1860, Agee 1994, Harrod et al. 1999). Contemporary landscapes are mostly dominated by stands of increasingly dense small pine, Douglas-fir, and grand fir (Agee 1994). Crown-fire potential is widespread within the Central Zone (Figure R) despite large areas burned by wildfire in the past decade that are currently at low risk of crown fire. Many areas at higher elevations have high crown-fire potential, but are in moist forest types (Figure G) and therefore are at low risk of stand-replacing fire. Departures from pre-settlement fire regimes in moist forest environments are generally not as great as changes experienced in dry forest environments (Agee 1994). However, contiguous areas of dry and mesic forest between the Wenatchee River Ranger District and Entiat Ranger District in the vicinity of Maverick Saddle have high-risk crown-fire potential (Figure R). The 1970s wildfire areas also have crown-fire potential and are at high risk of stand-replacing fire. The risk of crown fire and density-related insect outbreaks will continue to increase in these areas.

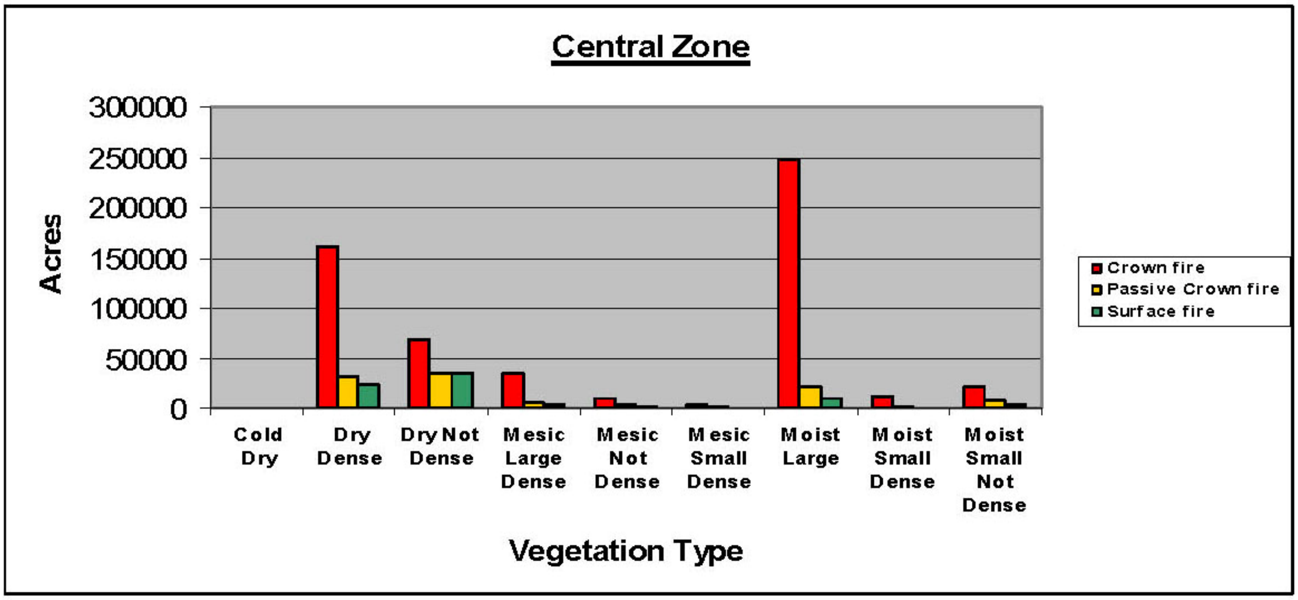


Figure S. Acres at risk of crown and surface fire, by vegetation type and structure, Central Zone

As much as 150,000 acres of dry dense forest in the Central Zone may be at high risk of stand-replacing wildfire (Figure S). In addition, at high risk of stand-replacing wildfire are nearly 50,000 acres of the dry not-dense forest. This finding suggests two possibilities: (1) our vegetation mapping misclassified some areas in this zone that should have been mapped dense, or (2) we over-estimated crown-fire potential. It is possible that both situations are true, given that a number of assumptions in our analysis could lead to disparities at the landscape scale. In any case, areas of dense dry and mesic forest are numerous in the Central Zone.

Our analysis of the Central Zone did not include recent wildfires or dry forest restoration activities, such as the Pendleton Project or Swakane fuels treatments. These activities have lowered the risk locally of stand-replacing crown fires. Recent fires on the Entiat and Chelan Ranger Districts have temporarily reduced risk of crown fire within the areas that burned.

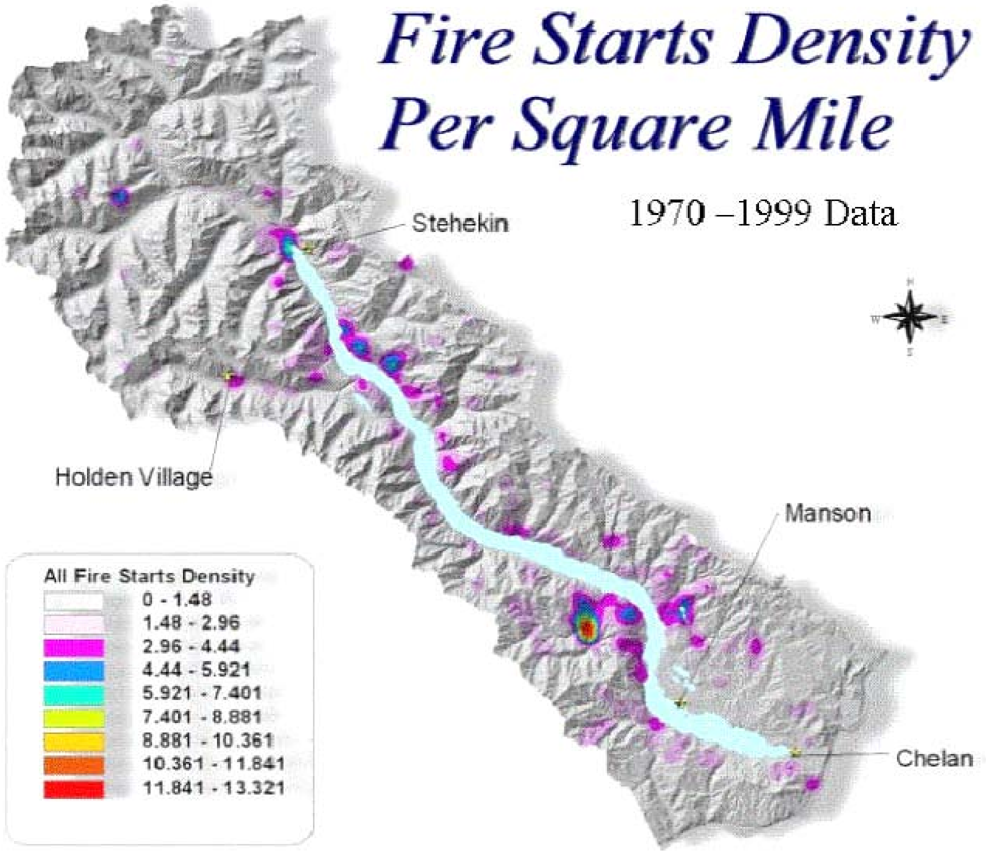


Figure T-1. Fire start density map displays where the most fire starts have occurred, per square mile, over the last thirty years. Data set from 1970-1999, Central Zone (USDA 2003).

Fire starts have been numerous on Central Zone Ranger Districts and surrounding ownerships (Figures T-1, T-2). Most of the starts are at mid and lower elevations in dry and mesic forest types. Fires are initiated by both natural causes (lightning) and human causes. As is the case in the North Zone, much of the high cost of suppressing recent wildfires is associated with preventing fire from crossing the Forest boundaries onto private lands where homes and other structures are located.

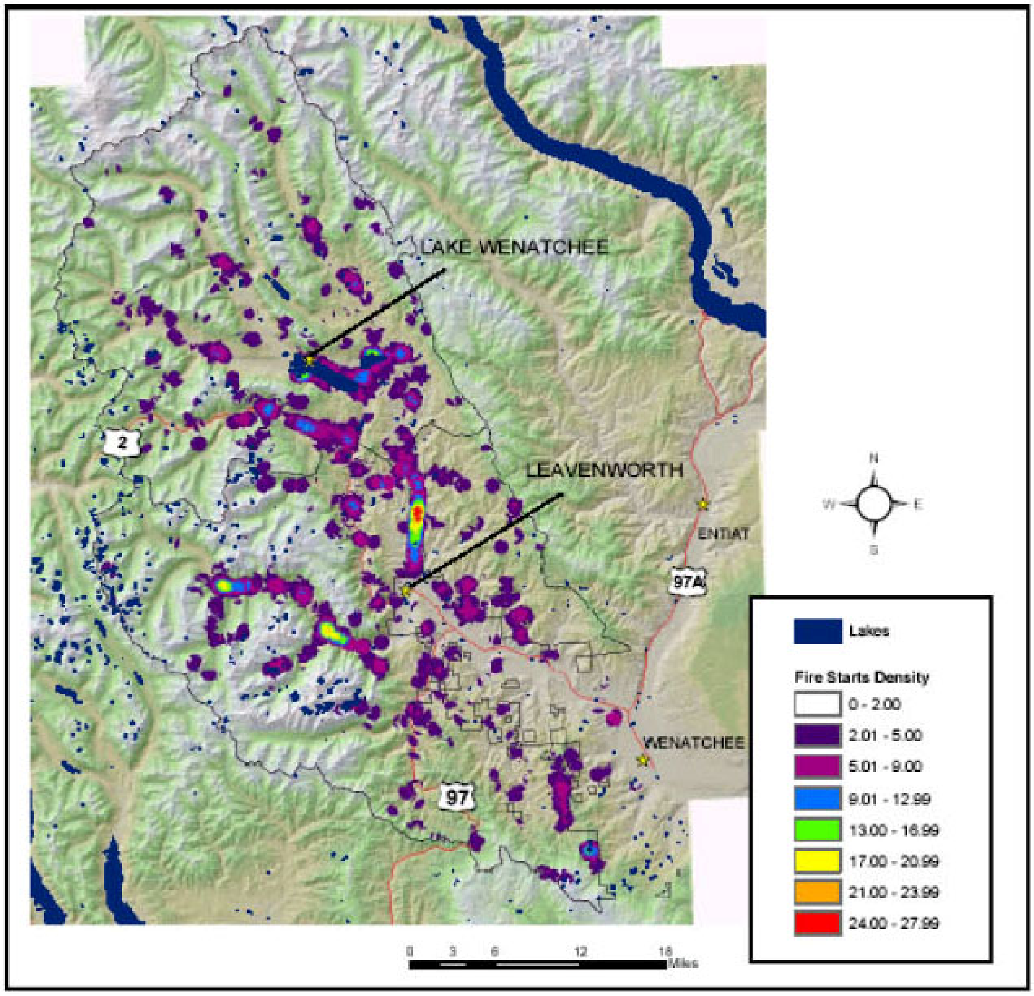


Figure T-2. Fire start density map displays where the most fire starts have occurred, per square mile, over the last thirty years. Data set from 1970-1999, Central Zone, (USDA 2003).

South Zone

Ranger Districts on the South Zone have had relatively little large wildfire activity since the 1970s. Based on preliminary information, about 125,000 acres of dry and mesic forest are within the wildland urban interface in the South Zone. Several large developments being built along the Forest boundaries on former industrial forest properties and agricultural lands will result in substantial increases in the wildland urban interface. Several communities and many small tracts with homes and improvements are adjacent to the Forest. There are also many summer homes under Forest Service permit located within the Forest boundary.

Dry and mesic forest types have departed from historical disturbance regimes, which were characterized by low-severity, high-frequency fires (Agee 1993, Hessburg et al. 1999). Historically, the majority of dry forest landscapes were dominated by open, park-like stands of largely ponderosa pine. Now landscapes are dominated mostly by stands of dense small pine, Douglas-fir, and/or true fir (Agee 1994).

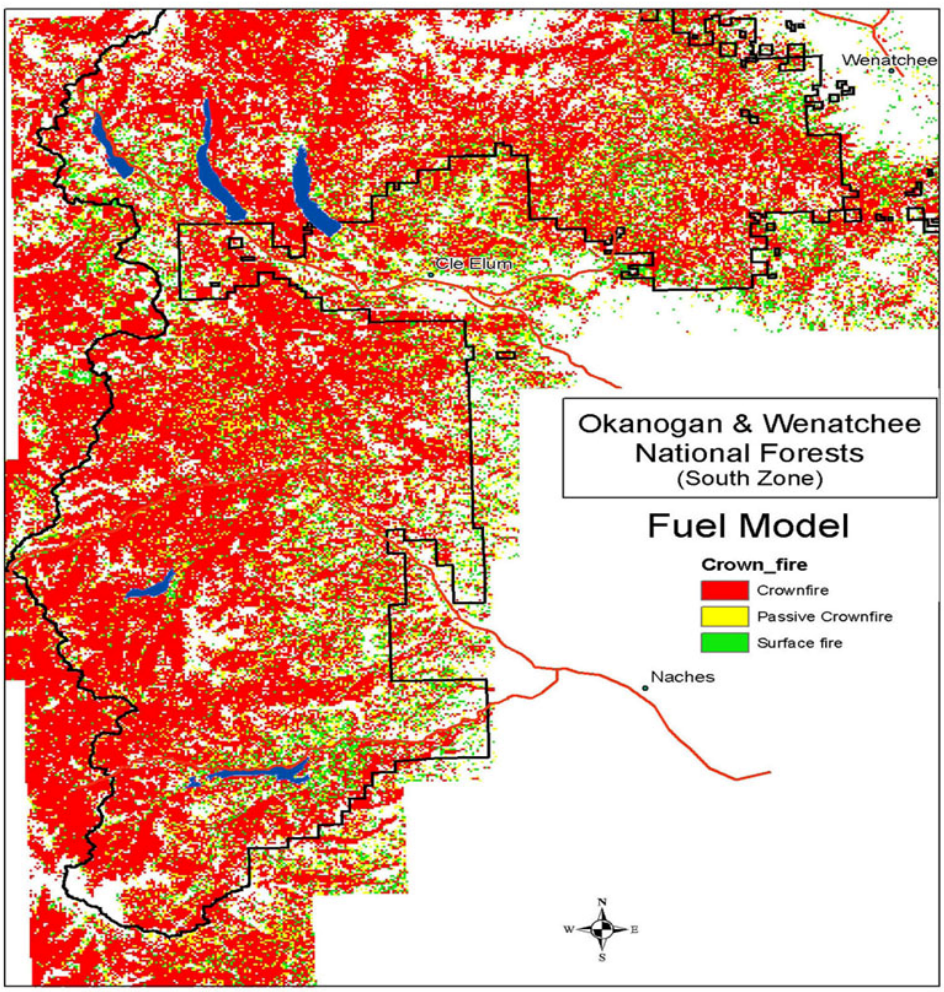


Figure U. Crown-fire potential, South Zone

Crown-fire potential is extensive within the South Zone (Figure U) and is present in all vegetation types (Figure H). Many areas at higher elevations and areas in the west part of the Cle Elum Ranger District have crown-fire potential, but occur in moist forest types and therefore are considered at low risk to stand-replacing fire. Dry and mesic forest types, however, are at high risk of experiencing crown fire. The recent spruce budworm activity in the Rimrock Lake and Divide Ridge area (Figure N) is leading to increased insect-mediated mortality. Surface fire potential is likely to increase, but crown fire potential is not likely to increase above the current level (Agee and Hummel 2003). However, given the high density of fire starts in this area (Figure U), the potential exists for increased surface fire activity. High fire starts are also found along the highway 410 corridor near Cliffdell, which is a wildland urban interface area.

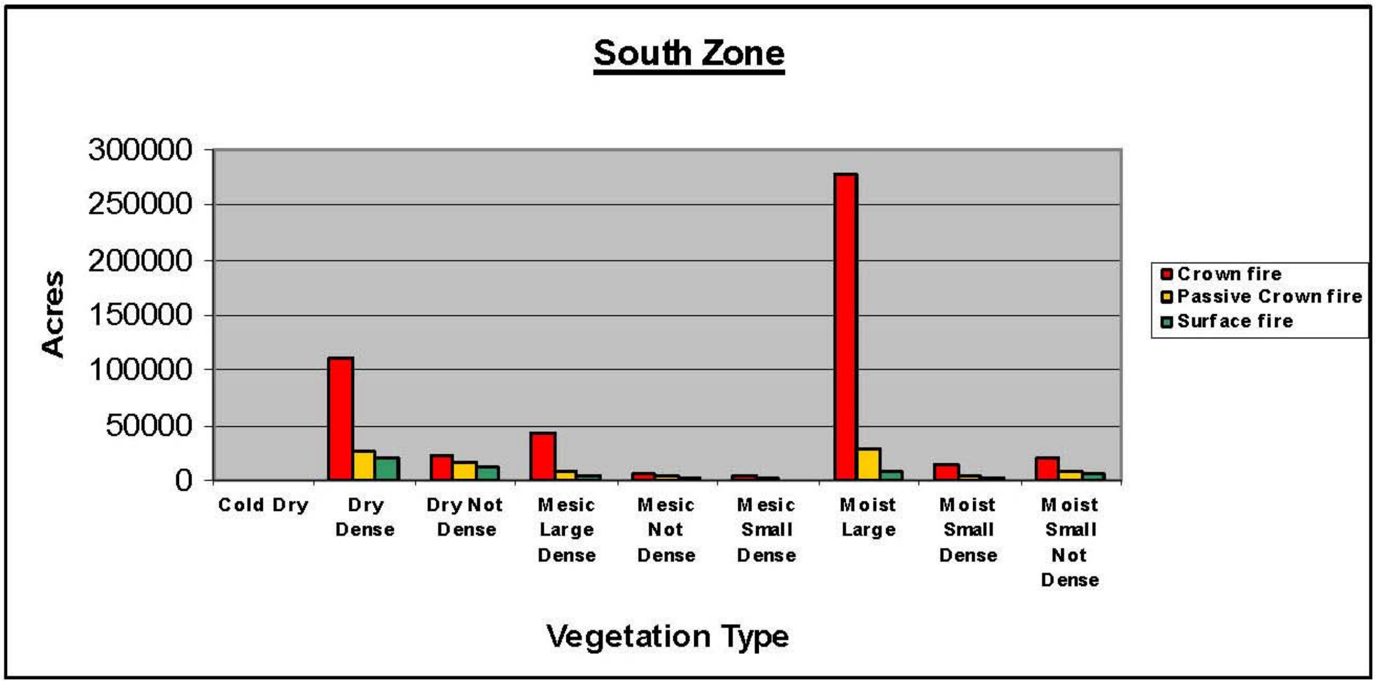


Figure V. Acres at risk of active crown, passive crown, and surface fire, by forest type and structure, South Zone

Approximately 160,000 acres of dry and mesic dense forest in the South Zone is at risk to crown fire (Figure V). This number may be lower because our analysis did not include areas recently thinned or treated by prescribed fire, particularly on the Naches Ranger District. On the Cle Elum Ranger District stands in the Swauk and Teanaway Watersheds are currently at high risk of large-scale stand-replacement wildfire. Most of this area has a relatively high density of fire starts (Figures W-1, X).

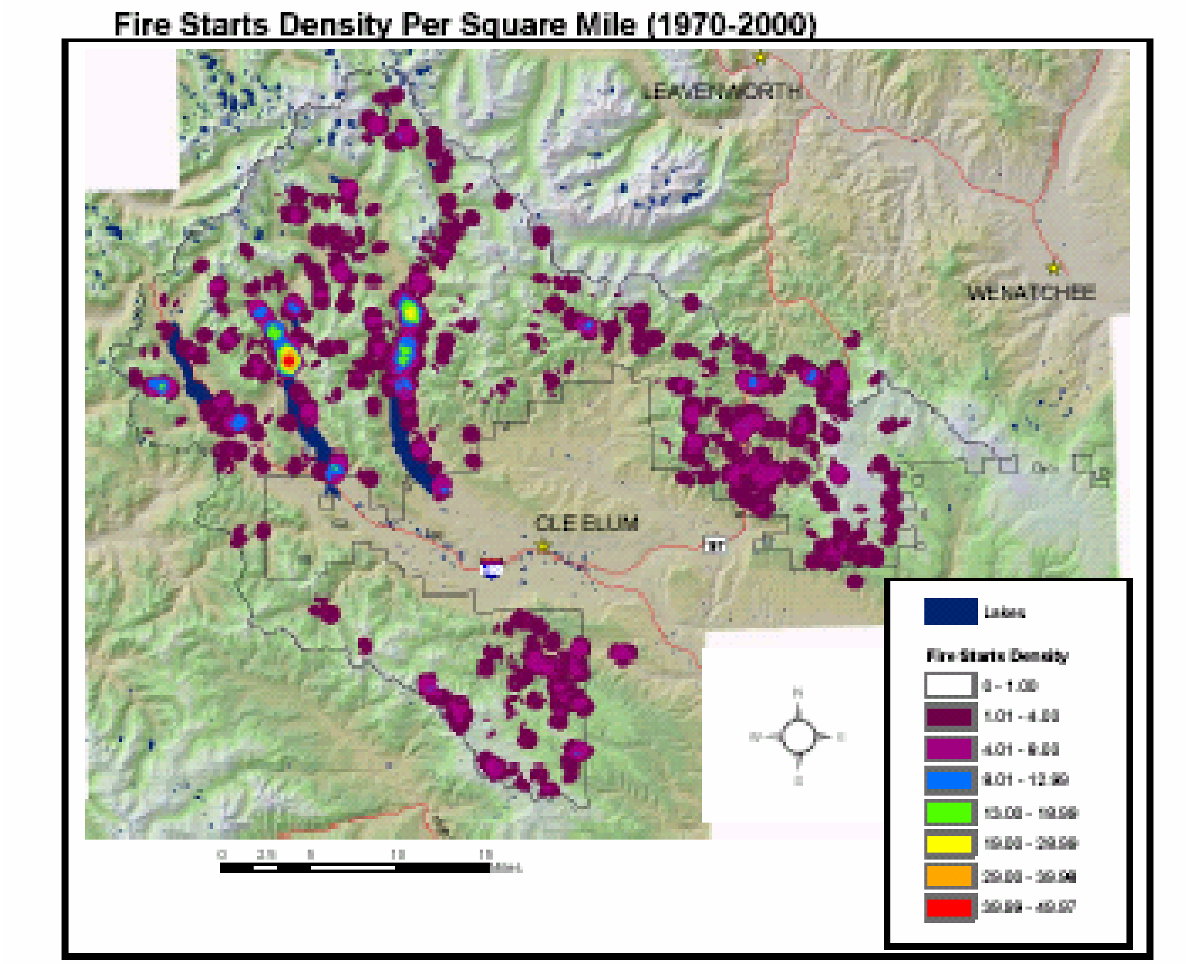


Figure W-1. Fire start density map displays where the most fire starts have occurred, per square mile, over the last thirty years. Data set from 1970-2000, South Zone, (USDA 2003).

Recent fire scar data analysis from the Swauk found it had the highest pre-settlement frequency of fire on the Okanogan and Wenatchee National Forests (Keenum, personal communication). Fire starts recorded over the past several decades in the Swauk corridor show that the average density of starts is 1 to 4 per year (Figures W-1, W-2). The potential for large fire exists from any given start occurring in the summer season.

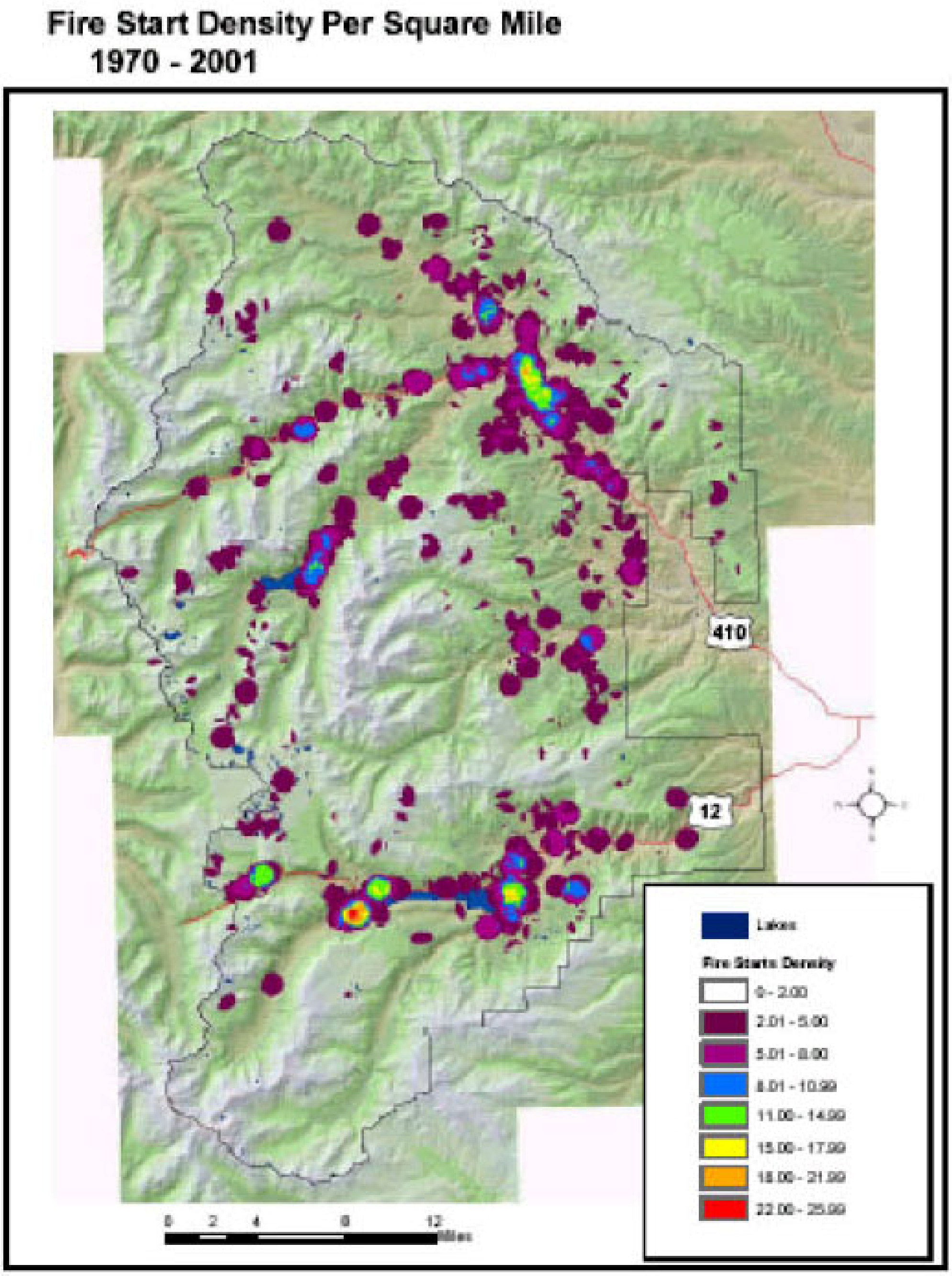


Figure W-2. Fire start density map displays where the most fire starts have occurred, per square mile, over the last thirty years. Data set from 1970-2001, South Zone, (USDA 2003).

In the South Zone, approximately 275,000 acres of moist large forest are at risk to crown fire (Figure V). These areas have a relatively low risk of large-scale stand replacement wildfire. The current trend of warming climate (Millar and Woolfenden 1999) may increase the probability that this area will experience large crown fires.

On the Cle Elum Ranger District, the Swauk and Teanaway Watersheds support large forested areas that are currently at high risk of insect epidemic and large-scale stand-replacing wildfire. These areas have the greatest amount of contiguous dense dry and mesic forest types on the Okanogan and Wenatchee National Forests, a large amount of intermingled human habitation, numerous areas of concentrated human activity, and high populations of spotted owl. On the Okanogan and Wenatchee Forests, forested lands within the Swauk and Teanaway Watersheds are among the least resilient to wildfire, insects, and disease.

Wildlife

In this section, we present the findings of our assessment of the current condition of habitats for focal wildlife species across the Okanogan and Wenatchee National Forests. This provides an assessment of the relative health of wildlife habitats for focal species, in light of expected potential disturbances from fire, insects, and diseases, and climate changes. We then project the condition of habitats for focal wildlife species over the next twenty years, given the current capacity to manage vegetation and the expected frequency and extent of disturbances.

Flammulated Owl and White-Headed Woodpecker

Currently, an estimated 514,255 acres of dry forest-not dense are potential habitat for these species on the Okanogan and Wenatchee National Forests. This represents an approximate 55% decline in the availability of the dry forest open habitat compared to pre-settlement reference conditions. This decline is largely a result of fire exclusion that has allowed dense tree understories to develop, and of past timber harvest that removed large old ponderosa pine trees (Hann et al. 1997, Hessburg et al. 1999, Wisdom et al. 1999). Vegetation types used by the flammulated owl and the white headed wood pecker are shown in Table 5.

Vegetation type	Potential flammulated and white-headed woodpecker habitat	Potential lynx denning habitat	Potential lynx foraging habitat	Potential spotted owl habitat
Dry-not-dense	X			
Dry dense	X			X
Mesic large dense				X
Mesic dense				X
Moist small dense		X	X	
Moist large		X	X	X
Cold dry		X	X	

Table 5. Vegetation types used in the Okanogan and Wenatchee National Forests Health Assessment; potential habitats used to assess lynx, flammulated and white-headed woodpecker, and the northern spotted owl

Because fire exclusion allowed fuels to accumulate and past logging removed the more fire-resistant large, old pines, sustainability of dry forest habitats for flammulated owls and white-headed woodpeckers is of significant concern (Harrod et al. 1999, Everett et al. 2000). The potential for large-scale, high-intensity fire that would eliminate remaining habitat is high (Harrod et al. 1999, Everett et al. 2000).

An additional consequence of fire exclusion and past timber harvest is that the connectivity of ponderosa pine forest habitats has declined, while Douglas-fir and grand fir cover has increased (Hessburg et al. 1999).

The availability of old ponderosa pine forest habitats for flammulated owls and white-headed woodpeckers is expected to decrease by 5%-10% over the next twenty years as a result of high intensity, stand-replacement fires. Dry forest treatments, such as thinning and prescribed fire, could be used to offset the potential loss of these habitats to stand-replacing fires.

As discussed earlier, the potential for large-scale high-intensity fires within dry forest habitats used by flammulated owls and white headed wood peckers is high. High intensity fires were not characteristic of pre-settlement disturbances in these habitats and would likely result in loss of habitat (Harrod et al. 1999, Everett et al. 2000). Loss of habitat may be further exacerbated because warming climate is predicted to increase the risk of severe fires in western forests (Alvarado et al. 1998; and discussed previously). Dry and mesic site treatments, such as thinning and prescribed fire, could improve the sustainability of these habitats, but the extent of this improvement depends on the resources available to implement the strategy. Dense dry and mesic forest habitats that have high fuel loads and lack large old ponderosa pine and Douglas-fir trees will take many decades to restore.

The connectivity of the old ponderosa pine forest habitats to facilitate wildlife movements is likely to decrease even further as a result of high intensity fires. Again, habitat connectivity could be improved depending on the resources available to implement Dry Forest Strategy restoration treatments.

Northern Spotted Owl

Currently about 595,378 acres of potential spotted owl habitat occur within the dry forest, 224,936 occur within mesic forest types, and about 898,846 acres of potential spotted owl habitat occur within moist forest types (Table 6).

	Dry		Mesic		Moist	
Forest	**Current**	**Projected**	**Current**	**Projected**	**Current**	**Projected**
Okanogan	172,698	167,698	114,339	101,896	147,559	115,635
Wenatchee	422,680	373,291	110,597	108,307	751,287	746,287
Total	595,378	540,989	224,936	210,203	898,846	861,922

Table 6. Current and projected availability of potential northern spotted owl habitat

The extent of the early-seral forest type is generally above the natural variability; the extent of late-seral forest types, which make up potential spotted owl habitat, was below the natural variability (Lehmkuhl et al. 1994, Hann et al. 1997). Habitats used by northern spotted owl are shown in Table 4.

The potential is high for large-scale high-intensity fire within potential spotted owl habitat that occurs within dry and mesic forests. As previously discussed, disturbance regimes in dense dry and mesic forests are significantly altered from pre-settlement conditions (Agee and Edmunds 1992, Everett et al. 1997, Gaines et al. 1997). Grand fir and Douglas-fir that dominate dense dry and mesic forests are highly susceptible to defoliating insects, bark beetles, and root disease. The risks of fire, insects, and diseases make it difficult to sustain structural attributes of spotted owl habitat. About 40%, or 65 spotted owl activity centers, are located within dry and mesic forest types (USDA FS 1997, 1998). Suitable spotted owl habitat within the moist forest types likely functions closer to pre-settlement disturbance regimes (Agee 1993) and is not as serious a problem relative to their sustainability. However, when moist forest types are contiguous with dense dry forest habitats, they are more difficult to sustain (Everett et al. 1997).

Currently potential spotted owl habitats within dry and mesic forests are more fragmented than they were historically (Hessburg et al. 1999). In the last century, within the dry forest successional advance has created islands of spotted owl habitat. The connectivity of moist forests has declined from historical levels (Hessburg et al. 1999). This is likely a result of management activities, such as timber harvest and fire exclusion (Hann et al. 1997).

The availability of potential spotted owl habitat within the dry forests is projected to decrease by 10% and in mesic forests by 7% over the next fifteen to twenty years. Habitat losses are likely to result from large-scale fires, and, to a lesser extent, from management activities. The availability of potential spotted owl habitat within moist forest is projected to decrease by 4% as a result of fires and management actions within the same period of time.

The likelihood of large-scale high-intensity fire within potential spotted owl habitat in dry and mesic forests is high. Disturbance regimes in habitats within these forest types are altered from pre-settlement conditions (Agee and Edmunds 1992, Everett et al. 1997, Gaines et al. 1997). As a result of this, the sustainability of these habitats is a concern and could be further exacerbated by influences of global warming (Alvarado et al. 1998; for further discussion, also see the Fire section in this document). Suitable spotted owl habitat within the moist forest types likely functions closer to their pre-settlement disturbance regimes (Agee 1993) and sustainability is of less concern.

The connectivity of potential spotted owl habitat will likely be reduced by large-scale, high-intensity fires. The extent and location of these fires, combined with the Dry Forest Strategy restoration treatments, will determine how well the late-successional reserve network will function.

Canada Lynx

Currently, about 1,461,000 acres provide potential Canada lynx habitat on the Okanogan and Wenatchee National Forests. Hann et al. (1997) suggest that as a result of fires and even-age harvesting within subalpine fir forests within the Columbia River Basin, early seral forest types are more abundant compared to pre-settlement conditions. However, at the watershed scale Lehmkuhl et al. (1994) showed that successional advance was indicated in the Methow basin by a 28% increase in the area of stands with subalpine fir and Englemann spruce understories. Even-age harvest units that have been pre-commercially thinned may not provide conditions to sustain snowshoe hare populations. Vegetation types that provide habitat for Canada lynx are shown in Table 5.

The potential for a high-intensity large-scale fire may be considerable for forest types associated with lynx habitat, but their disturbance regimes have not likely been altered much by fire exclusion (Habeck 1985, Agee 1993). Historically, wildland fire and insects have played the dominant roles in maintaining a mosaic of successional stages in lynx habitat (Ruediger et al. 2000).

Lynx tend to use coniferous forested vegetation during daily movements and generally avoid crossing large openings that are greater than 100 meters wide (Koehler 1990, Staples 1995). In some parts of the Columbia Basin, as a result of timber harvest activities (Hann et al. 1997), the area and connectivity of forest types that provide potential lynx habitat components has declined from those of pre-settlement conditions (Hessburg et al. 1999). Hann et al. (1997) and Wisdom et al. (2000) found that early seral forests within forest types across the Columbia Basin that compose lynx habitat are substantially more abundant than occurred in the early to mid-twentieth century. Work by Schellhaas et al. (2001) and Lehmkuhl et al. (1994) within the Okanogan National Forest suggest that locally the amount of early seral forest is reduced compared to pre-settlement conditions, primarily because of fire exclusion. Most lynx habitat on the Okanogan and Wenatchee National Forests is roadless, and has therefore never been affected by timber harvest. Even-age young forest that has been pre-commercially thinned may not provide conditions to sustain snowshoe hare populations. Research currently underway may clarify the relationship between thinning and snowshoe hare abundance.

Following disturbance by fire or timber harvest, the availability of forage habitat for Canada lynx may decrease for a short period. It is expected to increase within 15 to 20 years depending on site productivity. Based on local experience and vegetation projections using the Forest Vegetation Simulator, young lodgepole pine forest conditions favorable for snowshoe hare habitat may persist for 15 to 20 years. Disturbances such as fire, insects, and diseases are necessary for the continuous availability of lynx habitat components that are well distributed across the landscape.

The potential for a high-intensity large-scale fire may be considerable for forest types associated with lynx habitat, but their disturbance regimes have not likely been altered much by fire exclusion (Habeck 1985, Agee 1993). However, global warming may contribute to an increase in high-intensity fires (Alvarado et al. 1998) or may alter the capability of some mid-elevation sites to support lodgepole pine (Millar 2003b). Historically, wildland fire and insects have played the dominant role in maintaining a mosaic of successional stages in lynx habitat (Ruediger 2000). The sustainability of lynx habitat is not an issue except where it occurs adjacent to dry forest that has been altered by fire exclusion. Global climate change that may result in warmer conditions may reduce the extent of subalpine fir habitats, and reduce the area in the moist forest type in northeastern Washington.

The succession of subalpine fir forests may increase the connectivity of lynx habitats. The degree to which this occurs depends on the extent and location of fires.

VI. Conclusions

Our conclusions are drawn from examining the current situation, findings, and the projected outcomes for vegetation, insects and diseases, wildfire, and wildlife habitat. These conclusions fall into several categories:

Potential loss of life and property to wildfire

Significant changes to forest vegetation during the past century

Implementation of the Dry Forest Strategy and its need to be updated

Inadequate financial and human resources

Time required to plan and implement projects

Implications of changing climate

The current structure of vegetation and the condition of fuels create a high risk of severe wildfire in the wildland urban interface.

Wildfires burning in all forest types have a high potential to cross the Forest boundaries onto most private, state, and Tribal lands, and some locations along the Canadian border.

Wildfire poses a significant risk to human life, property, and resources.

The risks wildfire poses to adjacent ownerships cannot be mitigated on federal lands alone. Corresponding and cooperative efforts must also occur on adjacent ownerships.

The acreage of dense, multiple-canopy forest vegetation in dry and mesic forest types is increasing at a rate that exceeds current and projected treatment levels.

The amount and distribution of dense, multiple-canopy forest is unprecedented compared to pre-settlement conditions.

Existing vegetation in dry and mesic forests is unsustainable under current and anticipated climatic conditions.

There is substantial risk that wildfire will destroy important late-successional wildlife habitat.

Dense, multiple canopy dry and mesic forest is at risk from insect outbreaks.

Understory trees in existing shelterwood and seed tree harvest units are unlikely to grow to large size, nor will stands attain desired future conditions where numerous dwarf mistletoe infected overstory trees are retained and understory trees are host species.

New knowledge should be incorporated into the Dry Forest Strategy.

Disturbances designed at the stand and multiple stand levels should be evaluated in the context of the landscape in which they occur. Landscape level strategies to reduce potential for large wildfire events have been suggested by Finney (2001) and Agee et al. (2000). Finney (2001, 2003) suggests that well-designed and appropriately placed treatments which reduce fuels on 20% to 30% of the landscape may significantly mitigate wildfire size and intensity. Treatments that alter the density, composition, and structure of forest vegetation within individual stands must be commensurate with management objectives for the landscape.

Wildlife species dependent on dry and mesic forest types may also benefit from strategic, landscape-scale application of an updated Dry Forest Strategy. The management dilemma is that while fire exclusion may have increased the amount of suitable spotted owl habitat, it has also resulted in a greater risk of habitat loss from wildfires.

Thinning, other mechanical treatments, and prescribed fire are appropriate tools for managing stand density, forest composition, and structure. Prescribed burning and mechanical removal of biomass also mitigate accumulated fuels. Large accumulations of fuel on some landscapes will require mechanical treatment before prescribed fire can be applied with safety.

Mesic forests have many similar characteristics of dry forest and will respond to fire, thinning, and other disturbances in a similar way.

Mesic forest types adjacent to and upslope from dry forests provide important habitat for threatened, endangered, and sensitive wildlife species. They are at also at risk to wildfire, insects, and diseases. Much like dry forest types, mesic forests are often associated with the wildland urban interface.

Several years of drought and the potential for climatic warming may increase the risk of wildfire within dry and mesic forests over and result in larger, more severe fires than experienced in the past.

Human and financial resources available for necessary restoration activities are inadequate for treating sufficient acres forest wide to reverse the trend of increasing fires and insect outbreaks.

The National Forest budget is projected to be flat or declining for the next few years. This has translated into flat or declining acreages treated to reduce fuels and restore low intensity fire regimes near the wildland urban interface, and in dry and mesic forest types.

While some acres in roaded areas may be treated using timber sales or stewardship contracts, the majority of acres treated may not produce material that has commercial value.

Fire for Resource Benefits under the Okanogan and Wenatchee National Forests Fire Management Plan may be used to cost-effectively restore habitats, manage fuels, and manage fire risk in roadless areas and wilderness.

Each year significantly greater financial resources are expended on fire suppression than are invested in fuels treatments and stand management that would mediate or prevent severe fire effects. Investments to reduce fuels and thin may generate substantial long term savings in the costs of wildfire suppression.

The time required to plan and implement forest health and fuels reduction projects is excessive and must be reduced.

On average over ten years is required to plan and complete timber sales. Prescribed burning or thinning and fuels treatments projects may also require several years to plan and implement.

Dense forest conditions and abundant accumulated fuel found on much of the Okanogan and Wenatchee National Forests cannot be sustained under current or predicted climatic conditions.

> Warmer climatic conditions may bring an increased risk of large, landscape-scale insect epidemics and severe wildfire events that may result in the loss of habitat for threatened, endangered, and sensitive wildlife.
>
> Global climate change may alter temperature and moisture regimes over the next fifty years. Changes in climate may affect the abundance, distribution, density, and composition of forest vegetation. Warmer conditions may increase insect and disease-related tree mortality and increases in fuel on the forest floor. This may cause significant increases in acres burned in all forest types.
>
> Millar (2003a and 2003b) suggests that "managers should anticipate future climate change and ecosystem response when formulating plans." NAST (2000), Dale et al. (2001), and Dale et al. (2000) also suggest that management should anticipate climate change and manage vegetation to reduce vulnerability and to enhance recovery from disturbance.

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Appendix A: Forest Health Assessment Vegetation Layer

Query logic was developed by John Townsley and Connie Mehmel, 15 January 2003.

Forest Types

Four forest types were used to assess forest health conditions on the Okanogan and Wenatchee National Forests:

- Warm dry/Hot dry forest
- Mesic forest
- Moist forest
- Cold dry forest

Shrubland and grass land vegetation types were not addressed in this analysis. Coverages used to derive the forest types differ between ranger districts on the Okanogan and Wenatchee National Forests. We used the following GIS coverages to derive the forest vegetation covers for the Forest Health Assessment:

- PAG Layer (Henderson et al., most current layer) was used for all ranger districts
- Utah State University (1998) forest vegetation coverage for deriving the forest types for the Methow Valley and Tonasket Ranger Districts
- Neiman (1998) forest vegetation coverage for deriving forest types for the Chelan, Entiat, Wenatchee River, Cle Elum, and Naches Ranger Districts.

Warm Dry/Hot Dry Forest

Warm dry/Hot dry forest has been mapped for both the Okanogan and Wenatchee National Forests during development of the Dry Forest Strategy. We will use these existing maps as is. Other forest type coverages will be built on this assumption.

Dry forests are defined as forests that were historically open and supported widely-spaced, large ponderosa pine, western larch, and Douglas-fir in the overstory with little underbrush and only occasional clumps of smaller trees. This forest is typified by the low fire severity regime. These dry forested areas dominate the eastern edge of the Wenatchee National Forest, generally on landscapes that receive less than 30 inches of annual precipitation, elevations below 4,000 feet on the northern portion of the Forest and 4,500 feet on the south portion of the Forest. On the Okanogan and Wenatchee National Forests, areas considered dry forest generally occur below 4,300 to 4,600 feet in elevation, and are in proximity to the Methow, Chewuch, and Okanogan River Valleys or their major tributaries. Dry forest types were identified and mapped during development of the Dry Forest Strategy. The dry forest type includes all of the plant associations within the ponderosa pine and Douglas-fir series, and the drier plant associations within the grand fir series (USDA FS 2000).

GIS criteria used to develop the Warm dry/Hot Forest coverages for the two national forests were:

Okanogan: The coverage of dry forests for the Okanogan National Forest was created using an elevation limit of 4,300 feet on northerly aspects, 4,600 feet on southerly aspects, and

Douglas-fir series.
Wenatchee: A map of dry forests for the Wenatchee National Forests was developed using Forest Vegetation Series. A model was developed as a means of segregating dry grand fir plant associations from mesic grand fir series. The model mapped dry grand fir plant associations in areas with less than 30 inches of annual precipitation, and the grand fir series in areas with more than 30 inches of annual precipitation on west, southwest, south, and southeast aspects.

Mesic Forest

Wenatchee (Neiman) GIS Coverages

Mesic Forest = ABGR Series + PSME Series
Not Dry Forest

Mesic Large Tree Dense = Mesic Forest
cc> = 40%
Structure = 4, 5, 6, 7, 8, 9, 10

Mesic Small Tree Dense = Mesic Forest
cc >= 40%
Structure = 1, 2, 3

Mesic Not Dense
cc < 40%

Okanogan (USU) GIS Coverages

Mesic Forest = PSME Series
Not Dry Forest

Mesic Dense = Dense Forest
cc >= 40%

Note: Mesic Dense is expected to have a large proportion of "large" tree.

Mesic Not Dense = Mesic Forest
cc <40%

Moist Forest

Wenatchee (Neiman) GIS Coverages

Moist Forest = ABLA2 + PIEN + TSHE + ABAM + TSME + Series

Moist Large Tree = Structure code 4, 5, 6, 7, 8, 9, 10

Moist Small Tree Dense = Structure code 1, 2, 3 and cc >= 40%

Moist Small Tree Not Dense = Structure code 1, 2, 3 and cc < 40%

Okanogan (USU) GIS Coverages

Moist Large Tree = Structure codes 2, 3

Moist Dense Small Tree = Structure code 1 and cc >= 40%

Moist Open Small Tree = Structure code 1 and cc < 40%

Cold Dry Forest

Wenatchee (Neiman) GIS Coverages

Cold Dry Forest + LALY, PIAL

Okanogan (USU) GIS Coverages

Cold Dry Forest = LALY, PIAL

Appendix B: Criteria to Evaluate Effects on Wildlife Habitat

The following table summarizes the criteria used to evaluate current and projected forest health conditions on focal species wildlife habitats.

Table B-1. Effects on wildlife habitat evaluation criteria

Assessment criteria	Canada lynx	Northern spotted owl	Flammulated owl and white-headed woodpecker
Current condition	**Subalpine fir habitat**	**Late-successional forest habitat**	**Old ponderosa pine forest habitats**
Suitable habitat availability	Approximately 1,461,000 acres of lynx habitat are identified on the Forests. Currently there is more early-seral forest than occurred historically, as a result of fires and timber harvest in subalpine fir forests (Hann et al. 1997, Wisdom et al. 2000). Pre-commercial thinning of early-seral forests may not provide conditions to sustain snowshoe hare populations.	**Dry and mesic forests** Currently about 595,378 acres of potential spotted owl habitat occur within the dry forest; 224,936 occur within mesic forest types. **Moist forests** Currently about 898,846 acres of potential spotted owl habitat occurs within moist forest types.	An estimated 514,255 acres of potential habitat for these species are on the Okanogan and Wenatchee National Forests. This represents an approximate 55% decline in the availability of these habitats compared to reference conditions. This decline is largely a result of fire exclusion and past timber harvest (Hann et al. 1997, Hessburg et al. 1999, Wisdom et al. 1999).
Habitat sustainability	The potential for a high-intensity large-scale fire may be considerable for forest types associated with lynx habitat, but their disturbance regimes have not likely been altered much by fire exclusion (Habeck 1985, Agee 1993). Historically, wildland fire and insects have historically played the	**Dry and mesic forests** The potential for large-scale high-intensity fire within potential spotted owl habitat that occurs within dry and mesic forests is high and is outside of the inherent disturbance regime (Agee and Edmunds 1992, Everett et al. 1997, Gaines et al. 1997). As a result, the	The sustainability of dry forest habitats for flammulated owls and white-headed woodpeckers is currently of significant concern. Fire exclusion has allowed fuels to accumulate and past logging removed the most fire-resistant large old pine trees (Harrod et al. 1999, Everett et al. 2000). As a result, the potential for large-scale, high-intensity

Table B-1. Effects on wildlife habitat evaluation criteria

Assessment criteria	Canada lynx	Northern spotted owl	Flammulated owl and white-headed woodpecker
	dominant role in maintaining a mosaic of successional stages in lynx habitat (Agee 1999, Ruediger et al. 2000). Where lynx habitat occurs in close proximity to dry forests (such as on Table Mountain), fires that start in dry forests and burn at intensities outside the inherent disturbance regimes could affect adjacent lynx habitat.	sustainability of these habitats is a concern. **Moist forests** Suitable spotted owl habitat within the moist forest types are likely within their inherent disturbance regime (Agee 1993). The sustainability of these forests is more of a concern when moist forests are contiguous with dense dry forests.	fire within these habitats is high and has departed from the inherent disturbance regime (Harrod et al. 1999, Everett et al. 2000).
Habitat connectivity	The area and connectivity of forest types that provide potential lynx habitat has declined from historical conditions (Hessburg et al. 1999). This is largely a result of timber harvest activities (Hann et al. 1997). Koehler (1990) reported that lynx do not readily cross large openings (>100 m) during daily movements.	**Dry and mesic forests** Currently potential spotted owl habitats within dry and mesic forests are less connected then historically (Hessburg et al. 1999). This is because fire exclusion has resulted in an increase in dry dense forests on naturally fragmented landscapes. **Moist forests** The connectivity of moist forests has declined from historic levels (Hessburg et al. 1999). This is likely a result of fires and management activities (Hann et al. 1997).	The connectivity of ponderosa pine forest habitats has declined as Douglas-fir and grand cover has increased, a result of fire exclusion and past timber harvest (Hessburg et al. 1999).
Future Projection	**Canada lynx**	**Northern spotted owl**	**Flammulated owl and white-headed woodpecker**
	Subalpine fir habitat	**Late-successional forest habitat**	**Old ponderosa pine forest habitats**

Table B-1. Effects on wildlife habitat evaluation criteria			
Assessment criteria	**Canada lynx**	**Northern spotted owl**	**Flammulated owl and white-headed woodpecker**
Suitable habitat availability	The availability of forage habitat may decrease for a short period following disturbance (fire) but is expected to increase within 15-20 years. Disturbances such as insects, disease, and fires are necessary to provide for the availability of habitat components that are well distributed across the landscape. Global climate change may reduce the availability of these habitats.	**Dry and mesic forests** The availability of potential spotted owl habitat within the dry forests is projected to decrease by 10% in the dry forest and by 7% in mesic forests. **Moist forests** The availability of potential spotted owl habitat within moist forest is projected to decrease by 4%.	The availability of old ponderosa pine forest habitats for flammulated owls and white-headed woodpeckers is expected to decrease by 5-10% over the next 20 years as a result of high intensity, stand-replacement fires. This reduction could be offset depending on the resources available to implement dry forest restoration treatments.
Habitat sustainability	The potential for a high-intensity large-scale fire may be considerable for forest types associated with lynx habitat, but their disturbance regimes have not likely been altered much by fire exclusion (Habeck 1985, Agee 1993). Historically, wildland fire and insects have played the dominant role in maintaining a mosaic of successional stages in lynx habitat (Agee 1999, Ruediger et al 2000). The sustainability of lynx habitat that is adjacent to dry forest may be improved through the	**Dry and mesic forests** The potential for large-scale high-intensity fire within potential spotted owl habitat that occurs within dry and mesic forests is high and is outside of the inherent disturbance regime (Agee and Edmunds 1992, Everett et al. 1997, Gaines et al. 1997). As a result, the sustainability of these habitats is a concern. The areas treated under the dry forest strategy would improve the sustainability of a small portion of these habitats. **Moist forests** Suitable spotted owl habitat within the moist forest types are likely within	The potential for large-scale high-intensity fires within dry forests is high and is outside the inherent disturbance regime (Harrod et al. 1999, Everett et al. 2000). The sustainability of these habitats is a concern. The dry forest strategy could improve the sustainability of these habitats but the extent of this improvement is dependent on the resources available to implement dry forest restoration treatments.

Table B-1. Effects on wildlife habitat evaluation criteria

Assessment criteria	Canada lynx	Northern spotted owl	Flammulated owl and white-headed woodpecker
	implementation of the dry forest strategy.	their inherent disturbance regime (Agee 1993).	
Habitat connectivity	There is not likely to be much change in the connectivity of potential lynx habitats during the time frames considered in this assessment. However, succession of timber harvest units could increase habitat connectivity.	**Dry and mesic forests** The connectivity of potential spotted owl habitat will likely be reduced by large-scale, high-intensity fires. **Moist forests** The connectivity of these forests will not likely change much within the timeframes considered in this assessment.	The connectivity of the old ponderosa pine forest habitats to facilitate wildlife movements is likely to decrease even further as a result of high intensity fires. Again, habitat connectivity could be improved depending on the resources available to implement dry forest restoration treatments.

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Appendix C: The Scale of the Restoration Problem

Annual Treatment to Restore Pre-Settlement Stand Densities and Structures

Pre-settlement landscape conditions are often described as resilient to fire, insects, and diseases. An estimate of the number of acres of dry and mesic forest that must have existing fuel loading and tree densities reduces to pre-settlement levels is a useful measure of the potential size of the restoration task. Determining the number of acres that must be treated requires an estimate of the proportional representation of vegetation structures and species, an estimate of the acres of disturbance from management or natural causes, and an estimate of the time it takes for forest vegetation to re-densify.

Analysis and Discussion

The area of dense forested conditions in the dry and mesic forest types has increased since the turn of the twentieth century. The amount of densification is not precisely known. For the purposes of this assessment, the Forest Health Assessment team estimated that in 1934, when the Forest Service initiated the 10:00 a.m. Policy requiring immediate and aggressive suppression of all wildfires, about 10% of dry forest and about 40% of mesic forest was in a dense condition. This is a very conservative estimate of the pre-settlement structure of the landscape. Several authors have reported significant changes in the acres burned by wildfire beginning around 1900. Thus several years of succession and forest growth would have occurred by 1934 when the 10:00 a.m. policy was established.

Using GIS forest vegetation covers created for this Forest Health Assessment, the acres currently within each forest type and density class were determined. Table C-1 shows the acres of dense and not-dense-dry and mesic forest extant in 1998.

Forest Type	Acres
Dry dense	664,734
Dry not-dense	407,682
Total dry	1,072,416
Mesic dense	327,883
Mesic not-dense	108,067
Total mesic	435,950

Table C-1. Acres of dry and mesic forest type

Table C-2 shows the estimated distribution of acres between dense and not-dense conditions in 1934. The proportion of acres in dense and non-dense conditions was estimated by the assessment team based on professional judgment.

Forest Type	Acres
Dry dense	66,473
Dry not-dense	1,005,943
Total dry	1,072,416
Mesic dense	174,380
Mesic not-dense	261,570
Total mesic	435,950

Table C-2. Acres of dry and mesic forest type, 1934

The period during which forest vegetation re-establishes substantive fuel ladders or closed canopy conditions was estimated based on nearly twenty-three years of experience observing forest vegetation densification on the Okanogan and Wenatchee National Forests, and by using the Forest Vegetation Simulator (Dixon 2003) to model tree response in post-disturbance conditions.

On average, dry and mesic forest re-densifies in about twenty years following disturbance. Based on this, in the absence of disturbance, all of the dry and mesic forest would be in a dense condition within a relatively short time. Densification of forest can be reversed by either management actions such as thinning and prescribed fire or by natural causes, primarily wildfire.

The acreage of dry and mesic forest disturbed during the past twenty years by wildfire or prescribed fire, and the acres treated by mechanical methods of timber harvest or non-commercial thinning, was estimated from Forest Service records. Records from annual reports for the period between 1993 and 2002 were used for mechanical treatments. Annual reports from the period between 1990 and 2002 were used for prescribed fire. Wildfire acres were estimated from GIS files of large fires (100 acres or larger) between 1993 and 2002. For the purposes of this analysis, it was assumed that most of the area treated by mechanical methods and by prescribed fire between 1993 and 2002 were in dense dry forest. Adjustments to the historic acres treated are described below. Wildfire acres for the period between 1993 and 2002 were segregated by forest type. It was assumed that all mechanical treatments and prescribed fire treatments reduced the density of forest vegetation. Acres treated by prescribed fire between 1983 and 1989 were estimated from accomplishment records for the period between 1990 and 1993.

To account for treatments outside of dry and mesic forest types, we excluded mechanical treatments by the Wenatchee River Ranger District, along with 50% of accomplishments by the Cle Elum District, and 25% of the accomplishments of the Tonasket, Naches, and Methow Ranger Districts. Proportions excluded were based on personal knowledge of historic treatment patterns in dry, mesic, and moist forest types.

Many mechanical treatments and wildfire disturbances occur on the same acre. For example, following timber harvest or non-commercial thinning each year, some proportion of the areas that are mechanically treated are also subjected to prescribed fire. Following large wildfires, some proportion of the area burned may have dead trees removed in a salvage sale or by a non-commercial mechanical treatment. It is estimated that 70% of the harvested acres on the Entiat and Chelan Ranger Districts and 10% of the area harvested on the Tonasket, Methow Valley, and Leavenworth Ranger Districts were in salvage sales following stand-replacing wildfires. For this analysis it is assumed that 50% of acres harvested in timber sales or non-commercially thinned were likely to be subsequently treated with a prescribed burn. The prescribed burn may lag two or more years after the mechanical treatment. It is estimated that about 20% of the acres mechanically treated with timber sales were subsequently pre-commercially thinned during the past decade. It is estimated that 25% of the area mechanically thinned were treated with prescribed fire within five years.

Records of management activities prior to 1993 are not readily available. Therefore, to estimate the acreage treated for the twenty year period needed for vegetation to re-densify after disturbance it was necessary to project treated acres back in time. During the 1980s there were very few acres of prescribed fire; however, the number of acres mechanically thinned and harvested was substantially higher than experienced in the last decade. For the twenty-year period between 1983 and 2002, the acres of dry and mesic forest treated by mechanical means were estimated to be 150% of the adjusted acres treated between 1993 and 2002. During the past twenty years, roughly 520,000 acres of dry and mesic forest have been disturbed by wildfire and management activities. This is approximately the acreage of dry and mesic forest presently in a not-dense condition (see Table C-1).

Dry and mesic forest responds rapidly to disturbance. Natural regeneration of native conifers re-establish and grow at a rate such that treatments designed to reduce stand density and maintain open canopy remain effective on most dry and mesic sites for about twenty years. In the absence of further disturbance from mechanical treatments, prescribed fire, or wildlife, areas of dry and mesic forest that are presently in a non-dense condition are expected to revert to dense forest within about twenty years. Based on this, the loss of open forest conditions is estimated to occur at a rate of approximately 25,000 to 34,000 acres a year.

After reviewing recent management within the Columbia Basin, Quigley et al. (1996) observed that "continuing to manage vegetation using historical levels and approaches of stand management is unlikely to reverse trends in vegetation conditions." During the past decade, the areas treated on the Okanogan and Wenatchee National Forests by mechanical methods and prescribed fire have averaged about 14,000 acres per year. It is clear that the area treated is well below the rate of re-densification.

Considering the effects of wildfire as well as management activities, a goal of returning the dry and mesic forest to the relatively open conditions that occurred before settlement would require that the rate of treatment substantially exceed the rate of re-densification. The treatment rate must not only reduce tree density at the landscape level; it must also maintain open conditions within areas that have been treated (Agee 1994).

The Forest Health Assessment team estimated that when the 10:00 a.m. Policy was instituted in 1934, about 241,000 acres of dry and mesic forest were in dense conditions (Table C-2). Today there are about 993,000 acres in a dense condition (Table C-1). This is nearly four times as many acres in a dense condition as existed only seventy years ago. Within about two decades, without wildfire or further density management treatments, the area of dry and mesic forest in a dense condition could increase to about 1,508,000 acres as forest vegetation in existing open areas closes in.

Reversing the trend toward forest densification will require reduction of forest density and fuel loads on a large number of acres. Some fuel reduction and forest density reduction will result from wildfires. Wildfire is not a desirable means for reducing forest density because effects cannot be controlled and there is substantial risk to human life, property, and resources. A goal of management is to minimize the acreage of wildfire. Management treatments, including prescribed fire, fire for resource benefit, and mechanical treatments, are the preferable means for reducing fuel loadings and forest density.

The following two scenarios are presented to provide a sense of perspective regarding the number of acres that need to be treated annually within dry and mesic forest types to restore pre-settlement structure to the landscape. While wildfire is not desirable because of large negative impacts, wildfire effects do include reduced forest density and fuel loadings. Therefore, acres burned by wildfire are included in the calculations.

The scenarios are presented to examine rapid (twenty years) and less rapid (forty years) restoration of pre-settlement landscape proportions. Both assume that restoring landscapes to pre-settlement conditions is a goal. In both scenarios approximately 752,000 acres of dense dry and mesic would have to be converted from its current dense condition to a non-dense condition. In addition, the 516,000 acres of existing non-dense dry and mesic forest would have to be maintained in an open condition.

In Scenario A, restoration in twenty years would require reducing fuels and forest density on approximately 63,000 to 72,000 acres annually. Wildfire has affected about 13,000 acres of dense dry and mesic forest annually for the last decade. It is likely that wildfire acreage will continue to burn at least this many acres each year for the foreseeable future. If this is the case, approximately 50,000 to 59,000 acres a year, in addition to any fire restoration acres, would have to be treated to re-establish open forest in the proportions that existed in pre-settlement times.

In Scenario B, restoration over forty years, restoration would require modifying stand density and structure about 51,000 to 60,000 acres per year.

Conclusions

This analysis is useful to establish a reference point for management. Restoration of pre-settlement forest conditions is often mentioned by managers and members of the public as a desired outcome of management.

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Appendix D: Time between Project Inception and Completion

On average, existing timber sales on the Okanogan and Wenatchee National Forests require over ten years to plan and implement. Seventeen closed and currently active timber sales drawn from across the Forest were used to estimate the time required to:

1. Identify a need for action.
2. Assess environmental impacts and complete required NEPA documents.
3. Prepare and sell the sale.
4. Complete harvest treatments.
5. Complete post-harvest treatments (see Table D-1). Post-harvest treatments include reforestation, weed control, wildlife habitat projects, and disposal of logging slash and debris.

For the start date we used the date that a timber sale environmental analysis was first listed in the Schedule of Proposed Actions (SOPA). Contract duration was estimated by using timber sale sell and termination dates in the Timber Information Manager (TIM). Twelve of the seventeen sales still have timber to be harvested. Adjustments in the contract termination date may be granted for a variety of reasons. Adjustments may increase the contract time by anywhere from a few months to several years. Timber sales in the sample that are still active will probably require more time to complete than is shown in Table D-1.

None of the sales have all post-harvest work completed. Ranger District reforestation and fuels management personnel provided estimates of when the time needed to complete post-timber sale Brush Disposal (BD) and Knutson-Vandenberg (KV) funded trust fund work was completed. Typical post-harvest treatments accomplished with KV or BD trust funds include slash piling, pile burning, under burning, thinning, pruning, site preparation for planting or for natural regeneration of conifers, planting, wildlife habitat treatments, weed control, road rehabilitation, and other activities.

On average, a timber sale on the Okanogan and Wenatchee National Forests requires over ten years to plan and implement, including completing all BD and KV work. Time requirements range from small, simple sales that span about five years, to large complex sales that may take fourteen to over twenty years.

Table D-1. Time required to complete all harvest and post-harvest treatments

		Size			Years			
Ranger District	**Sale**	**Acres**	**CCF**	**MBF**	**To Plan**	**Timber Sale Contract[1]**	**Post Sale BD/KV[1] KV[2]**	**Total**
Cle Elum	Johnson Canyon SBA /Johnson Canyon Forest Health	767	5,524	2,858	2.7	3.4	3	9.1
Cle Elum	Currier Canyon/Johnson Canyon Forest Health	125	867	379	5.6	0.5	3	9.1
Entiat	Chicken Strips Salvage/	335	1,525	735	2.8	2.4	3	8.2
Entiat	Madcat Salvage/	34	494	258	5.8	1.4	3	10.2
Lake/Lea	Orchard Reoffer/Lower Peshastin	685	8,427	4,470	3.5	3.2	3	9.6
Lake/Lea	Bad Medicine/Fish Pole Ecosystem Restoration	415	7,244	3,832	5.3	2.8	3	11.1
Lake/Lea	Dumpy/Fish Pole Ecosystem Restoration	169	2,127	1,110	0.6	1.5	3	5.1
Lake/Lea	Cowcam/Lower Peshastin	857	7,957	4,037	4.4	3.3	3	10.7
Naches	Kaboom/Boomer	2,383	19,652	10,271	3.9	6.9	3	13.8
Naches	Elderberry/Elderberry	1,557	14,785	7,506	12.7	4.3	3	20.0
Naches	Rattle SBA/Rattle	1,344	10,026	5,152	0.6	4.4	3	8.0
Methow	Fawn	1,319	14,208	7,400	5.8	4.3	4	14.2
Methow	TPR	775	7,488	4,004	3.8	4.3	4	12.2
Tonasket	Oakley	426	2,651	1,314	1.9	4.0	4	9.9
Methow	Leecher Thin	1,822	9,207	4,373	1.2	6.6	4	11.8
Tonasket	Redmill	410	4,105	2,057	4.7	2.0	4	10.7
Tonasket	Conger	3,536	25,080	13,063	5.1	4.3	4	13.4
	Average Values	942	7,854	4,046	3.9	3.3	3.2	10.4

[1] Only three of the seventeen sales listed have all of the harvesting finished. Eight sales have less than 25% of the timber harvest completed.

[1]Completion
[2] Completion of post-harvest activities varies by ranger district. Some begin post-sale BD and KV treatments as timber sale units are logged and released. For example, the Entiat, Wenatchee River, and Naches Ranger Districts indicate that mechanical post-harvest fuels treatments and KV funded activities typically begin as Purchaser compliance work is accepted. However, where there is post-harvest burning, treatments don't begin until sales are closed. Other Districts, such as the Methow Valley and Tonasket Districts, do not begin post-sale treatments until logging is completed and all Purchaser requirements under the timber sale contract are met. Even on Districts where post-harvest treatments are initiated before sale closure, BD and some KV work is not completed until two to five years after logging is finished. Districts indicate that it takes three to five years to complete all work if post-sale treatments begin following sale closure.

Projects that manage natural fuels using a combination of prescribed fire and mechanical treatments were reviewed on a more informal basis than was the case with timber sales. Data on projects that are accomplished by Forest employees, or by service contract, are not readily available, so Ranger District fuels managers and Fire Management Officers were contacted on the Entiat, Tonasket, Naches, Chelan, and Wenatchee River Ranger Districts. According to their observations, it may take two years from inception to completion for very small (under 200 acres) projects, while 10 to 12 years may be required for larger or more complex fuels abatement projects. In many cases, natural fuels projects are intertwined with timber sales. Several fuels managers indicated that prescribed burning and non-commercial removals alone are unlikely to effectively reduce fuels.

Planning requires from two to over five years for larger non-commercial fuels projects. Most Districts mentioned changing priorities, changes in direction, and unavailable planning dollars as major factors in the extended timelines. Implementation of fuels projects is affected by smoke management concerns and seasonal burning restrictions. In some cases, smoke dispersal concerns may cause Ranger Districts to defer planned projects for one to several years.

Appendix E: Rationale for the Selection of Focal Wildlife Species Used in the Forest Health Assessment

Dry forest

Focal species: White-headed woodpecker and Flammulated owl
Rationale: Two focal species were identified for this group to represent the range of tree densities that occurs in this habitat and because this habitat was identified through the ICBEMP process as one of those that has been the most reduced in quantity and quality from historical levels (Wisdom et al. 2000). The white-headed woodpecker represents open habitats with large snags and pine trees (see Marshall 1997 for a review), and had the highest risk-factor sensitivity index score of this habitat group (USDA FS n.d.). The flammulated owl is more widely distributed and uses denser stands with smaller trees (Wright et al. 1997). The flammulated owl had a moderate risk-factor sensitivity index but in combination with the white-headed woodpecker, represented a wide-variety of risk-factors and forest management activities. Data on habitat associations from local studies are available for both species. Both of these species were selected as focal species in the North Cascades Landbird Conservation Plan.

Late-successional Mixed Conifer Forest (Mesic and Moist Forests)

Focal species: Northern Spotted Owl
Rationale: The northern spotted owl has a wide distribution across the assessment area and has been monitored for over ten years. Several studies have been conducted on the Wenatchee National Forest and have shown the northern spotted owl to be dependent upon structural attributes found in late-successional forest conditions (Buchanan et al. 1995, Everett et al. 1997, Buchanan and Irwin 1998, Herter et al. 2002). In addition, several studies have shown that spotted owls are sensitive to forest management activities (summarized in Thomas et al. 1990) such as those that would occur to address forest health issues. The northern spotted owl was selected as a species to monitor the effectiveness of the Northwest Forest Plan (Lint et al. 1999). For these reasons this species was selected as a focal species for late-successional forest conditions.

Cold Dry Forest

Focal species: Canada lynx
Rationale: Lynx are a wide-ranging carnivore whose habitat and foraging requirements are associated with subalpine-fir forests (Aubry et al. 1999). As a Federally listed threatened species, lynx habitat and populations are likely to be monitored. The lynx had the highest risk-factor sensitivity index within this group and a diversity of risk-factors were identified (USDA FS n.d.). This species was selected as a focal species by Wisdom et al. (2000) and is being recommended as a focal species for use in forest planning in the Pacific Northwest Region (USDA FS n.d.). Wisdom et al. (2000) reported that changes in source habitats for lynx have occurred in the North Cascades as increases in early-seral montane and subalpine forests and as subsequent decreases in mid and late-seral subalpine forests.

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