

Henry M. Jackson Hydroelectric Project
(FERC No. 2157)

**Habitat Management Methods
Literature Review and Evaluation**

Final Report
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List of Acronyms

BA	Basal area
BC	British Columbia
CMZ	Channel migration zone
CNB	Cavity Nesting Bird(s)
CT	Commercial thinning
CWD	Coarse woody debris
DBH	Diameter at Breast Height (4.5 feet above ground)
DecAID	<i>Decayed Wood Advisor</i> , a computer program/advisory tool
DEMO	<i>Demonstration of Ecosystem Management Options</i> study
DNR	Washington Department of Natural Resources
DOE	Washington Department of Ecology
FERC	Federal Energy Regulatory Commission
FPA	Forest Practices Act
GIS	Geographic Information System
GMA	Growth Management Act
GPS	Global Positioning System
GTR	Green tree retention
HEP	Habitat Evaluation Procedure
JHP	Jackson Hydroelectric Project
OMA	Old Growth Management Area
ORV	Off-Road Vehicle
PCE	Primary Cavity Excavator
PMF	Permanent Mixed Forest
PNW	Pacific Northwest
PUD	Public Utility District
PWP	Pileated Woodpecker
RD	Relative density
RHA	Riparian Habitat Area
RMA	Riparian Management Area
RMZ	Riparian Management Zone
ROW	Right-of-Way
SCN	Secondary Cavity Nester
SPTH	Site Potential Tree Height
T/E/S	Threatened, endangered, and sensitive
TL	Tolerance Levels, from DecAID management database
TPA	Trees per acre
TPH	Trees per hectare
USFS	U.S. Forest Service
USFWS	U.S. Fish and Wildlife Service
VDT	Variable density thinning
WHMP	Wildlife Habitat Management Plan
WMZ	Wetland Management Zone

EXECUTIVE SUMMARY

The Public Utility District No. 1 of Snohomish County (District) and the City of Everett (City), as co-licensees of the Henry M. Jackson Hydroelectric Project (FERC No. 2157) (Jackson Project), are involved in the Integrated Licensing Process prescribed by the Federal Energy Regulatory Commission (FERC). One of the relicensing process studies is a review of the scientific literature to identify advances in wildlife habitat management techniques that may be relevant and useful to the Jackson Project's Wildlife Habitat Management Plan ("WHMP", Snohomish County PUD and City of Everett 1988). The report consists of two parts: a literature review and an annotated bibliography. These documents were produced as specified in Revised Study Plan 6: Habitat Management Methods Literature Review and Evaluation (Snohomish County PUD and City of Everett, Sept. 12, 2006). One exception was made from the methods detailed in the Study Plan (Section 6.7.3): Differences in cost between alternatives and current techniques were not evaluated. The scientific literature provided very little information that could be readily used to identify the costs of implementing particular techniques on WHMP lands. Implementation costs are usually highly site-specific and are subject to baseline conditions and operational constraints; this analysis could be performed on WHMP lands as part of future planning for specific management tracts.

The literature review and evaluation process involved evaluating research and management-related documents and making contacts with scientists. Source documents were entered into a database from which the annotated bibliography was created (Appendix 1). All citations are numbered in the bibliography and they are referenced in the report text as bolded numbers, e.g. **(282)**. References are arranged by number in Appendix 2 and by author in Appendix 3.

The co-licensees' work benefited from including a number of review articles, annotated bibliographies and other syntheses of the literature prepared by scientists in universities and public agencies in the Pacific Northwest. Other highly relevant research programs are ongoing, and only computer simulations, experimental designs and/or early results of experiments were available for review. Because the potential benefits these studies may provide to the Jackson Project's habitat management program, the co-licensees will continue to monitor the progress of ongoing studies reported in this review. Important new findings that may improve the implementation of the WHMP will be evaluated, and if any of them are adopted, this information will be shared with the Jackson Project's agency reviewers. Over 300 documents and communications are currently included in the co-licensees' database of relevant information.

Information presented in this review is sorted according to the habitat management techniques employed by the WHMP on Jackson Project mitigation lands. Currently-used management techniques are grouped into one or more of the following broad categories:

- Forest vegetation management
- Streams, wetlands and buffer zones

- Coarse woody debris management
- Deer forage management
- Snag management
- Right-of-way management
- Nesting habitat

Information in each category was evaluated and a synthesis was prepared that describes the advances in scientific understanding and habitat management trends in the Pacific Northwest that are related to the WHMP's management techniques. Applications of the current research and management trends to the WHMP are summarized in the final two chapters of this report.

Although the WHMP's management objectives and techniques were developed 20 years ago, the current implementation of the program is generally consistent with more recent guidelines and recommendations. One reason for this is that the WHMP is an adaptive management program that allows for innovation and improvement; the co-licensees have made many such innovations within the structure of the WHMP over the years. A summary of relevant potential alternative management techniques is provided in Appendix 4.

Several themes in the recent literature on forest management techniques may be applicable to the WHMP and would involve variations of current WHMP management practices. In particular, the current literature suggests that the quantities and spatial patterns of green tree retention may be manipulated to improve understory development and forest stand structure for many wildlife species. Similarly, advances in commercial thinning techniques may enhance wildlife habitat benefits provided by the WHMP. Variations on clearcutting such as harvest with green tree retention and variable density thinning are expected to promote deer forage at least as well as clearcutting. However, research reports invariably emphasized that the choice (and expected results) of specific management techniques are highly site-specific. Thus the potential benefits of applying any technique to WHMP mitigation lands would depend on identifying site-specific opportunities and constraints in pre-treatment forest stands.

Current understanding of "legacy" elements in Pacific Northwest forests, including snags, coarse woody debris, and large decadent trees, and their benefits for wildlife species emphasizes retaining and promoting larger trees. Approaches to providing these elements include managing for levels similar to natural late-successional and old growth forests, and/or managing for particular wildlife species' needs. Given that most forest stands on WHMP lands are much younger, managing for snag-using species is appropriate and well-documented in the literature. Management direction for species that use coarse woody debris is not as well documented, although most reports emphasized the need to provide some large down wood. Comparisons between sizes and numbers of down wood reported in the literature and down wood quantities provided under the WHMP will require some additional measurements in the field.

Current trends in the management of priority habitats including riparian zones, streams and wetlands emphasize designation of buffer zones that preserve the ecological

functions of these habitats. The co-licensees' review of guidelines from various agencies benefited from the agencies' synthesis of the extensive scientific literature on the functions of these habitats. The primary interest in managing these priority habitats with regard to the WHMP stems from timber harvest activities. In addition to the WHMP's buffer zone rules, Washington Forest Practices rules offer the most relevant (and required) procedures for determining buffer zone widths and allowable activities where timber harvest is proposed in proximity to wetlands and streams.

Review of the literature on management of rights-of-way did not suggest any significant changes in management practices, nor did the review of artificial nest structures for birds. The co-licensees have practiced adaptive management in these areas throughout the implementation of the WHMP, and have documented activities in annual progress reports.

1.0 STUDY OBJECTIVES AND DESCRIPTION

As part of the Federal Energy Regulatory Commission (FERC) Integrated Licensing Process for the Henry M. Jackson Hydroelectric Project (Jackson Project), Public Utility District No. 1 of Snohomish County (District) and the City of Everett (City) agreed to conduct a Habitat Management Methods Literature Review and Evaluation. The purpose of this literature review and evaluation is to identify information relevant to the Wildlife Habitat Management Plan (“WHMP”, Snohomish County PUD and City of Everett 1988) that has been developed since the WHMP was prepared in 1988. Advances and alternatives in wildlife habitat management techniques currently in use on mitigation lands are discussed and evaluated relative to WHMP goals. District biologists have stayed current with various wildlife management techniques during implementation of the WHMP and changes have been made in management techniques in consultation with the wildlife agencies and documented in the WHMP annual reports. To implement the objectives of Revised Study Plan 6: Habitat Management Methods Literature Review and Evaluation, District biologists identified and reviewed relevant literature and information and communicated with other biologists who are working on similar issues and techniques. This is an evaluation of best scientific techniques on the management of WHMP lands and will assist in determining whether any alternative management techniques will be likely to improve success in achieving the WHMP’s goals.

The WHMP was developed by the District and City, co-licensees, in consultation with the agencies and Tulalip Tribes to compensate for habitat losses resulting from construction of the Jackson Project and its operation through 2060. It was submitted by the District and the City in 1988 and approved by the FERC in 1989. The WHMP has been implemented since its approval; however, “it is designed to accommodate changes and improvements in wildlife habitat management as they become available. Adjustments will be made to the existing prescriptions as needed, and new techniques will be substituted for existing ones if they are more effective and/or more economical, but all changes will be made within the single constraint of meeting the objectives of this plan.” (WHMP, p. 1-12). The objectives of the WHMP are described within Section 3 of the WHMP, under each management tract (i.e.: Sections 3.1.4, 3.2.4, 3.3.4, 3.4.4 and 3.5.4). Relicensing provides an opportunity to formally do what the co-licensees, agencies and Tulalip Tribes have been doing all along as specified in the WHMP: i.e. accommodating changes and improvements in wildlife habitat management on Project-related lands.

The WHMP directs wildlife habitat management activities on lands associated with the Jackson Hydroelectric Project as established, monitored and maintained in accordance with the Project license. This report identifies pertinent advances in management techniques from a review of recent scientific literature for the Pacific Northwest region. Alternatives to the management techniques currently in use under the WHMP are evaluated, with the objective of determining whether modifications to the WHMP would be likely to improve success in achieving the plan’s goals, which are identified below.

Construction of the Spada Lake reservoir during Stage I and Stage II of the Jackson Project in 1965 and 1984 respectively, inundated about 1,900 acres of habitat in the Sultan River basin. To offset this loss, and in response to the FERC Order Approving Aquatic Resources Mitigation Plan and Requiring Revised Terrestrial Resource Mitigation Plan for Project No. 2157, issued on August 22, 1984 (28 FERC 62,249), the District worked with the U.S. Fish and Wildlife Service (USFWS), Washington Department of Wildlife (now Washington Department of Fish and Wildlife (WDFW)), U.S. Forest Service (USFS), and the Tulalip Tribes to develop the WHMP (Snohomish County PUD and City of Everett 1988). As requested by these agencies and the Tribes, the WHMP' goals were designed to:

1. Mitigate for the loss of terrestrial habitat by creating or enhancing habitat similar to that which was lost;
2. Provide mitigation lands in the vicinity of the lost habitat whenever possible;
3. Emphasize the following types of habitat in the management plan: (a) old-growth coniferous forest, (b) mature riparian forest, (c) wetlands and (d) young riparian forest; and
4. Compensate for the average annual habitat units lost to the Project, as estimated by the Habitat Evaluation Procedure (HEP) study conducted by the WDW in 1982.

As part of the WHMP development process, the 1982 HEP was updated (Snohomish County PUD and City of Everett 1988) to quantify changes in wildlife habitat that had resulted primarily from construction of the Project. The HEP was also expanded to predict changes that would be likely to result from on-going Project operation, with and without implementation of the WHMP. The analysis was used to provide guidance on the adequacy of the draft plan and identify additional needs for the plan to make it acceptable to the wildlife agencies and the Tribes. Evaluation species were selected to represent habitat types in the project area. The HEP indicated that the draft WHMP (which did not include 1,745 acres of terrestrial habitat in the Spada Lake Tract that was obtained in the 1991 land exchanged and added to the WHMP) would provide full mitigation, or more, for 7 of the 10 evaluation species and 2 of the 4 priority cover types. The late-successional species (pine marten, pileated woodpecker and Douglas squirrel) would be mitigated over 110 percent, old growth would be mitigated over 200 percent and wetland habitat by over 140 percent. Young and mature riparian forest were shown to be mitigated less than 100 percent because of the difficulty in replacing that type of habitat. Three species (black-tailed deer, ruffed grouse and black-capped chickadee) would have been mitigated less than 100 percent because of the emphasis on late successional coniferous forest in the management plan. Changes in the plan for the Lost Lake and Lake Chaplain tracts following the HEP analysis provided more mixed forest and wetlands, and the addition of land (700 acres were required, 1,745 were provided) in the Spada Lake Tract, significantly increased the mitigation for these three species as

well as the others, and increased the amount of old growth, wetland and riparian habitat (see Section 6 of the WHMP for additional details).

The HEP analysis formed part of the basis for the negotiated agreement on the content of the WHMP. Since mitigation was not set to begin until the late 1980s, and as a proactive approach to meeting the requirements of the next license period (beginning in 2011), the WHMP was designed to account for impacts of Project construction and ongoing Project operation, and to provide mitigation benefits through 2060.

The WHMP was accepted by the wildlife agencies in 1988 and by FERC in 1989 (Order Approving with Modification Revised Wildlife Habitat Management Plan issued May 19, 1989). Since the Spada Lake Tract was acquired after the WHMP was formulated and accepted, a Spada Lake Tract Supplemental Plan was created, and approved by the FERC in 1997 (Order Approving Wildlife Habitat Management Plan Supplement for the Spada Lake Tract Issued April 18, 1997). The co-licensees continue to consult with the wildlife agencies and Tribes regarding implementation of the WHMP and advise them of any proposed changes and improvements. Since its inception, the WHMP has been subject to continual review and adaptive management, documented in Annual Reports and periodic meetings with resource agencies. Implementation of the WHMP is on schedule.

2.0 BACKGROUND INFORMATION: WHMP MANAGEMENT TECHNIQUES

The WHMP guides management of five tracts of land totaling approximately 7,070 acres (4,861 acres of land and 2,207 acres of reservoir and lake) (Figure 2.0-1). The District owns approximately 4,345 of these acres and the City owns approximately 2,688 acres (Table 2.0-1). The remaining WHMP lands are secured through easements.

The mitigation measures in the WHMP are designed to protect or modify existing forest, meadow and wetland habitats in the Project vicinity to enhance their value for the 10 evaluation species used in the HEP analysis. Since the WHMP was approved in 1989, operational access to the Spada Lake Tract has become limited, and emphasis has progressed toward management of late-successional species. It has become more difficult to provide open habitat for deer at Spada Lake, which would leave deer management opportunities primarily on Lost Lake Tract and Lake Chaplain Tract. The challenge remains to manage the WHMP lands most effectively for all habitat types and the species that represent them.

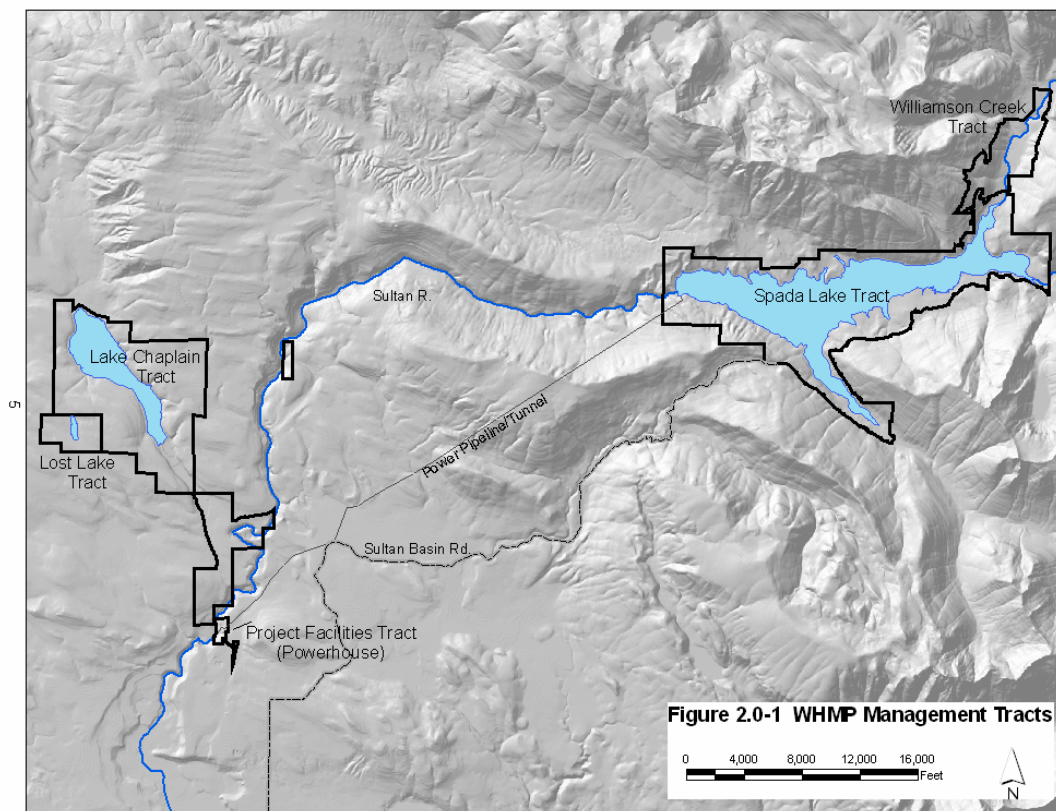


Table 2.0-1. WHMP management tract summary.

Tract / Size	Owner	Characteristics	Management Priorities
Lake Chaplain 2,237 acres of land; 451 acres of water*	City of Everett	Primarily second-growth conifer; includes mixed forest, wetlands, old growth and riparian habitat	Protect water quality; improve habitat quality; protect bald eagle nest site
Lost Lake 216 acres of land; 14 acres of water	District	Includes 14-acre lake and high quality wetlands	Protect wetlands; enhance riparian and upland forest; improve waterfowl nesting habitat
Project Facility Lands 74 acres of land; 3 acres of water	District, easements	Located around facilities and ROW where habitat was disturbed in the past	Minimize disturbance; enhance meadow, shrub, open woodland habitat
Spada Lake 1,978 acres of land; 1,719 acres of water	District	Spada Lake shoreline and 3 forest management units; primarily second growth conifer and mixed stands; also includes old growth, wetland and riparian habitat	Manage forests to promote old-growth attributes in Old Growth and East Management Units; provide a mix of age classes in South Shore Management Unit
Williamson Creek 356 acres of land; 20 acres of water	District	Old growth conifer forest, riparian habitat, and wetlands	Protect old growth forest, riparian habitat and wetlands

* No active management occurs on Lake Chaplain since it is strictly a water supply reservoir.

2.1 Forest Vegetation Management

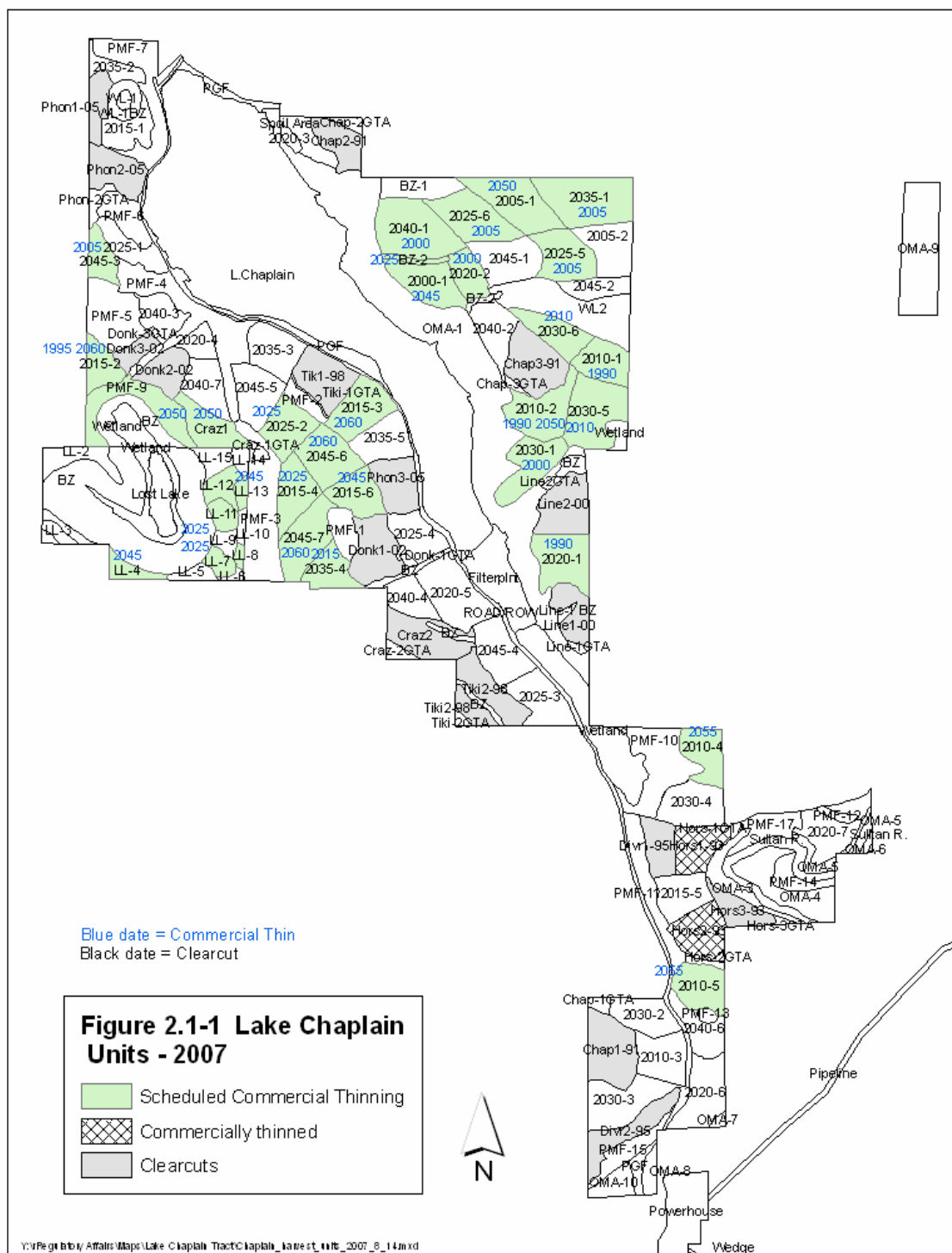
Forest Vegetation Management is a major component of the WHMP and will be ongoing through the life of the plan. The WHMP forest vegetation management program includes preserving and buffering all old growth stands, and promoting old growth characteristics in adjacent second growth stands. Most of the old growth in the Project area occurs on the Williamson Creek and Spada Lake tracts. Mixed and deciduous forests are preserved, as nature allows, with some intervention as needed to enhance habitat characteristics.

2.1.1 60-year rotation stands

WHMP management of 60-year rotation stands aims to reduce the time spent in unproductive successional stages, relative to standard forestry practices on industrial timber lands, specifically to:

1. Optimize availability of forage and interspersed cover for deer.
2. Maintain a constant acreage in the early-successional stand condition, increase production of grasses and shrubs on those acres.
3. Promote growth rates of overstory trees.

Approximately 1,290 acres of second growth coniferous stands at Lake Chaplain that were scheduled for harvest prior to becoming part of the WHMP are now managed on a 60-year rotation under the Plan. Harvest boundaries depicted in the WHMP have been updated to improve operational feasibility, reduce impacts to streams and wetlands, and reduce the length of access roads. As part of the process, boundaries of permanent mixed forest stands, stream and wetland buffer zones, and old growth management areas have been established. The timber harvest program complies with the WHMP's schedule and requirements, including the restriction on harvest unit size (Figure 2.1-1).



Small harvest units (less than 26 acres) and commercial thinning units are created and managed on a rotational basis to optimize the availability of forage and the interspersions of forage and cover for deer. The WHMP identified a total of 71 final harvest units (i.e. clearcut) on the Lake Chaplain Tract, with scheduled activity between 1990 and 2045.

Of these units, 25 (530 acres) are scheduled for commercial thinning during the period 1990 to 2060. Some of the original WHMP units (currently 70+ years old) are scheduled for thinning 25 years prior to final harvest. Other original units are scheduled to be clearcut first and commercially thinned 45 years later. The remainder are scheduled for final harvest only. Harvest units are spaced in location and time to create more edge and ensure forage and cover are always in close proximity. They are limited to a width of 1,200 feet because deer use decreases significantly at distances greater than 600 feet from cover (**259**), and forest cover is maintained around all harvest units until they are at least 15 years old.

Final harvest activities at Lake Chaplain began in 1991 and harvest has proceeded at the rate of two or three units every two or three years. The WHMP allows some flexibility in implementing final harvest, and the level of harvest has been within the allowable range in the WHMP's schedule. To date, 16 final harvest units totaling about 300 acres have been completed at Lake Chaplain and the stand condition has been converted from dense Small Sawtimber Conifer Forest to Early Successional Conifer Forest or Open-Canopy Sapling/Pole Conifer Forest. Two units totaling about 37 acres have been commercially thinned, with no change in cover type. The WHMP schedule called for commercial thinning of 10 units (comprising approximately 205 acres) by 2005 (not including the two that were actually thinned). The scheduled thinnings did not happen because access road systems were not in place or because the forester concluded that the unit was not suitable for thinning.

Existing snag trees are scarce in many Lake Chaplain units and most do not survive timber harvest; therefore, snags are created on harvest units. Section 2.3 of the WHMP details the reason for creating snags at the rate of 3 per acre (see Section 2.5). Green trees are left in a single clump or strip adjacent to a buffer zone or forest stand that has not been scheduled for harvest, at the rate of 0.25 ac of green trees per 5 ac harvested. The purpose of retaining green trees is to provide a supply of trees for future snag creation.

Following harvest, all final harvest units are seeded with a grass/forb mix on bare areas and replanted with 350 Douglas fir and western red cedar seedlings per acre. Cottonwood cuttings are sometimes planted in wet areas. Road ROWs are also seeded, and access roads outside the closed watershed have been gated to prevent vehicle access by the public.

Follow-up activities on forest plantations include monitoring of stocking levels, removal of excessive hardwoods ("brush control"), and pre-commercial thinning. The objective is to manipulate the number of tree seedlings and the species composition to approximate the goal of 5 to 10 percent hardwoods in the overstory, and about 300 trees per acre. Pre-commercial thinning was needed on the three 1991 final harvest units to reduce excessive conifer density, and some hardwood pockets in other harvest units were also reduced when natural in-seeding resulted in overcrowded tree seedlings.

Approximately 96 acres of mixed conifer/hardwood forest on the Lost Lake Tract is dedicated to 60-year rotation management, with the same goals and harvest methods as 60-year rotation conifer forest, but with several exceptions:

1. Maximum size of harvest units is limited to 10 acres to increase edge and enhance habitat for ruffed grouse and black-tailed deer.
2. Stands should be replanted with species mix to ensure 30% deciduous trees (cottonwood and maple preferably) at 45 years.
3. Stocking adjustments are to be performed on a spacing basis, retaining multiple species.

The Lost Lake mixed forest units were scheduled for harvest in the WHMP, and were thoroughly evaluated, but they have been indefinitely postponed because habitat values were good and would not benefit overall from harvest (Figure 2.1-1).

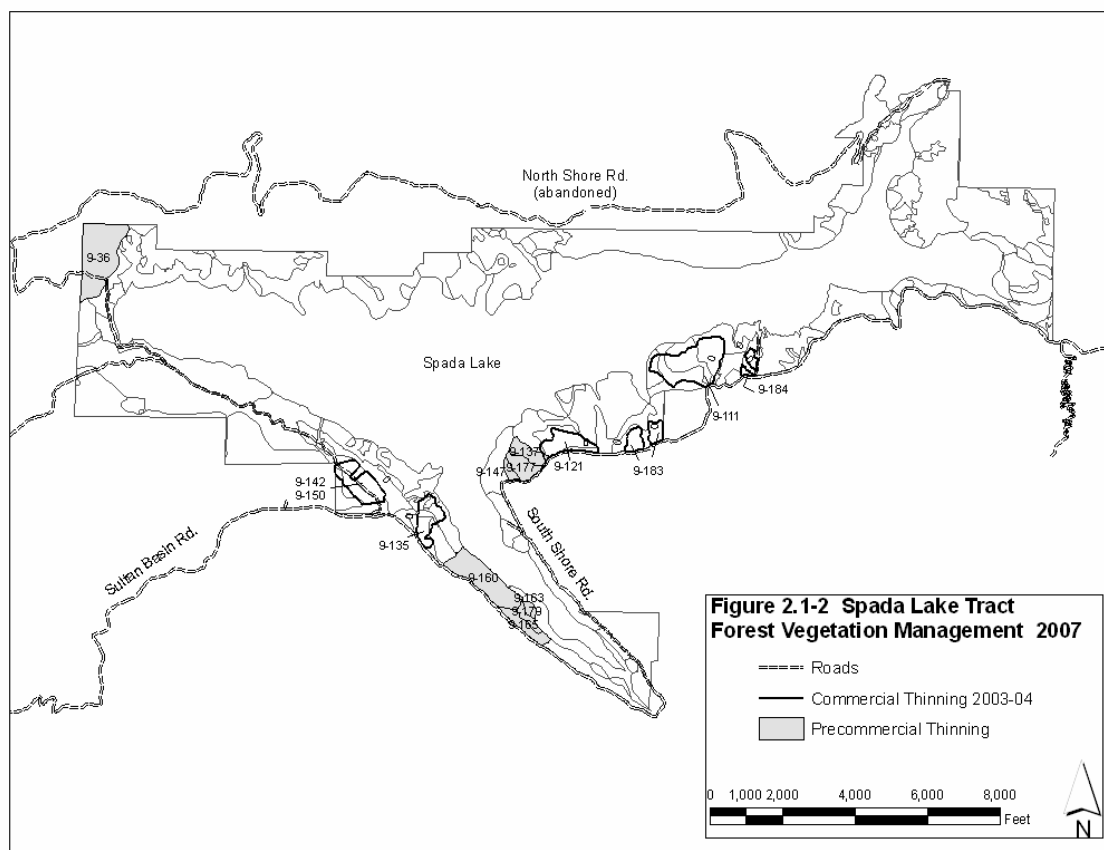
Precommercial thinning was conducted on 46 acres of the Lost Lake Tract in 1991 to improve wildlife habitat. No harvest activities are conducted on the Williamson Creek Tract.

The Spada Supplement (Snohomish County PUD and City of Everett 1997), a plan for the 1,745 acres of lands surrounding Spada Lake that were acquired in 1991, was approved by FERC in 1997. The goals of the plan are to:

1. preserve water quality;
2. preserve and enhance old growth, riparian and wetland habitats;
3. manage second growth forest primarily for deer with due regard for other species; and
4. consider aesthetics (viewshed) in planning and implementation of the supplemental plan.

The tract is divided into three management units based on vegetation, soils, accessibility and management objectives. Two of the management units (1576.2 acres) focus on late successional species. The third unit (390.5 acres) focuses on improving habitat for earlier successional species with an emphasis on deer, as requested by the wildlife agencies. Late successional characteristics are promoted by providing large snags, logs and forest gaps, and by thinning to promote a multilayered canopy. Forage production is increased by pre-commercial and commercial thinning to allow light to reach the understory. Three young second growth stands (totaling about 30 acres) on the south shore of Spada Lake were pre-commercially thinned in 1996. Two second growth stands (totaling about 38 acres) on the South Fork were pre-commercially thinned in 2000, and two stands (also totaling about 38 acres) in the northeast corner of the Spada Lake Tract were pre-commercially thinned in 2002. Eight stands (totaling about 100 acres) were commercially thinned in 2004 (Figure 2-1-2). Approximately 180 acres of second

growth conifer forest could potentially be commercially thinned and an additional 79 acres could be precommercially thinned in the next 10 yrs, depending on road access.



2.1.2 *Permanent mixed forest, deciduous and riparian forest*

Approximately 326 acres in the Lake Chaplain Tract, 80 acres in the Lost Lake Tract, 17 acres in the Project Facility Lands Tract, 54 acres at the Spada Lake Tract, and 55 acres at the Williamson Creek Tract are preserved as permanent mixed (PMF), deciduous and riparian forest with no clearcutting. Approximately 33 acres of mixed forest located in scattered stands will be incorporated into 60-year rotation coniferous forest units and protected during harvest. The WHMP recognizes that some units will not remain in mixed or hardwood type permanently, but will eventually become coniferous stands. The WHMP's desired species composition for PMF's is 30 % deciduous at stand age 45, and allows removal of conifers to achieve this without dropping canopy closure below 60%. Small patch harvest of 1 acre or less per 10 acres of PMF is allowed. To date, no small patch harvests have been implemented on these permanent forest units.

In addition to the acres of permanent forest designated in the WHMP, many forest stands in the Spada Lake Tract will likely not be scheduled for harvest. Only 100 acres have been commercially thinned to date, and assuming that an additional 180 acres of second growth coniferous forest are thinned (as directed by the Spada Supplement), over 1,424 acres coniferous and mixed forest in this tract are not planned for harvest in the future.

Most of these stands are located in the management units that are designated for promotion of late-successional characteristics.

2.1.3 Second growth forest/ understory management

Overstory management opens the forest canopy to 60% during commercial thinning (CT) and removes it at final harvest, to increase production of forage for deer and promote development of shrub and herb layers as habitat for smaller animals.

The WHMP calls for protecting desirable forage species during harvest, replanting trees at lower than normal density (250 trees per acre, or tpa), seeding units with grasses and forbs after final harvest and after CT. Fertilization is allowed outside the Lake Chaplain watershed.

2.1.4 Old growth coniferous forest

Existing old growth stands are preserved in the Lake Chaplain (62.5 acres), the Williamson Creek (369.8 acres) and Spada Lake tracts (218 acres). Management is passive, allowing removal of overstory trees only to maintain target snag densities. Younger stands are included in old growth management areas (OMA) at Lake Chaplain; with no harvest of these trees, except for thinning and patch clearings (less than 1 ac). Total acreage of old growth condition will increase unassisted by management, especially at Spada Lake where 1206 acres of second growth coniferous forest and mixed forest is not scheduled for future harvest, or may become inaccessible.

2.2 Streams, Wetlands and Buffer Zones

Wetland and Streamside buffer zones are implemented to protect the quality of wetlands and streams, and provide edge and travel corridors. Wetland buffers required by the WHMP vary from 200 to 500 feet and stream buffers vary from 50 to 200 feet in width.

2.3 Coarse Woody Debris Management

Coarse Woody Debris (CWD) management is an integral part of maintaining a healthy forest ecosystem over time. CWD provides habitat for many species of animals, large and very small. Managing CWD can also be important in helping wildlife species move safely through forested stands. The CWD management program calls for existing dead and down old growth logs to be left undisturbed on harvest units when possible and new material is provided during harvest. In addition to old growth logs found on site, an average of 8 undecayed or Decay Class 1 and 2 Douglas fir or hemlock logs, with an average diameter of 20 inches and minimum length of 20 feet, are left per acre during harvest activities.

To date, 327 live trees and many existing snags and logs that meet the criteria have been retained on Lake Chaplain clearcuts.

2.4 Deer Forage Management

Deer forage monitoring is also used to assist in determining if and when pre-commercial thinning is needed. Forage is sampled prior to harvesting to collect baseline data, and then at three-year intervals following harvest until the tree canopy closes and the understory layer becomes sparse. Deer forage monitoring has been conducted on eight of the Lake Chaplain harvest units to date following procedures developed in 1995. Forage utilization is measured by qualitatively assessing hedging.

2.5 Snag Management

Snags provide habitat for many species that use snags for nesting, roosting, hiding, foraging and food storage. The WHMP snag management program target is an average of 307 snags per 100 acres based on the needs of primary cavity nesting species (woodpeckers). The target includes hard and soft snags of varying widths and heights, with a minimum of 11 inches diameter at breast height (dbh) and 10 feet in height (Table 2.5-1). Inventory of existing snag trees, creation of additional snag trees, and long-term monitoring are part of the WHMP.

A total of 74 units (1,558 acres) have been inventoried on the Lake Chaplain and Lost Lake tracts, with all but one having had all necessary snag creation. The remaining unit (a nine-acre wetland buffer) is scheduled for completion in 2008. On those 74 units, 2,768 snags have been created.

Table 2.5-1. Target size distribution per 100 acres for snag trees on WHMP lands, based on primary cavity nester needs.

Diameter Range (inches)	Minimum Height (feet)	Hard Snags (Class 1-2)	Soft Snags (Class 3-5)
11.0-14.9	10		16
15.0-16.9	20	45	192
17.0-24.9	10		48
25 +	40		6

Numerous stands on the Spada Lake and Williamson Creek tracts are old-growth with abundant natural snags, and thus have required only inventories. To date, a total of 1,033 acres have been evaluated, with 2,157 snags created in 45 second-growth stands. Additional snag creation is planned for 2007.

2.6 ROW Management

Management of rights-of-way (ROW) in the WHMP focuses on three main objectives: a) increased production of grasses, forbs and shrubs for forage; b) placement of trees, shrubs and brush piles for cover and habitat diversity; and c) limiting human use, particularly off-road vehicle (ORV) use on the power pipeline ROW.

The ROW directly over the power pipeline is mowed annually in late fall to prevent tree seedlings from maturing. Portions of the ROW (where grasses and forbs have been slow to establish naturally) have been seeded with a mixture of ryes, fescues, and clovers, and fertilized to promote growth; most of the ROW is now covered with a healthy herbaceous layer. Native shrubs (primarily spirea and thimbleberry) are flagged and protected from mowing, where practicable. Boulders and logs have been placed along streams to prevent ORV access.

Noxious weed control has become one of the most important aspects of ROW management. Several techniques for control and eradication of Scotch broom and tansy ragwort have been used; hand-pulling of small infestations, repeated mowing/cutting during the growing cycle, and more recently, application of herbicide by a state-licensed applicator. Weed occurrences have been mapped for several years, using GPS. Locations will be entered into the Project GIS to improve the District's ability to monitor and follow-up on treatment success.

Right-of-way management also addresses plantings at project facilities and along Project roads adjacent to Chaplain Marsh and Lake Chaplain. These plantings are intended to increase vegetative screening and improve habitat values.

2.7 Nesting Habitat

Nesting Habitat Enhancement measures identified in the WHMP include three types of nest structures:

Waterfowl Nest Boxes provide nesting habitat for wood ducks, bufflehead and hooded mergansers. The WHMP calls for two nest boxes at Lost Lake. In 2004, the District had in place 12 boxes at Lost Lake, 6 boxes on the Lake Chaplain Tract, and 8 boxes at Spada Lake. All boxes are maintained and monitored annually. Nest box success is summarized in Table 2.7-1 below. It is important to note that waterfowl have not used the 8 boxes at Spada Lake, a factor which reduces the apparent overall success rate.

Nest boxes have been removed upon occasion, due to starling use, bear predation, or instability of the mount tree. New boxes are added to replace damaged boxes.

Table 2.7-1. Percent of available nest boxes that produced ducklings.

Year	1997	1998	1999	2000	2001	2002	2003	2004
Lost Lake	57	43	14	33	30	40	25	58
Lake Chaplain	67	0	20	71	33	50	57	33
Spada Lake	NA	0	0	0	0	0	0	0

Artificial Nesting Islands offer waterfowl a predator-reduced environment. Currently, there are two platforms at Lost Lake and two at Spada Lake. They are maintained and monitored annually. The floating platforms have been used for resting and feeding by waterfowl and otters, with the only breeding attempts noted to date being at Lost Lake.

Pied-bill grebes used one of the platforms at Lost Lake in 2001, and remnants of goose eggs were observed on the other platform in 2003.

Osprey Nest Structures can increase production by providing a large, stable nest platform. Osprey select the broad flat tops of trees, snags or artificial structures adjacent to lakes, rivers and reservoirs for nesting. The District has placed one nest structure at Lost Lake and two at Spada Lake by topping live trees and placing a platform upon them. Annual monitoring has indicated the nest structures have not been successfully used for breeding since 1995.

2.8. Monitoring and Reporting

The WHMP schedule requires implementation activity every year, and many activities such as monitoring are repeated annually. Annual progress reports are provided to the resource agencies and Tribes every year and to the FERC at 5-year intervals. All of the annual reports are available on the District's relicensing web page (<http://www.snopud.com/WaterResources/relicensing.ashx?p=2334>).

The annual progress reports are used to document details of implementation of the WHMP. The WHMP is a fairly prescriptive document in that it provides methods and a schedule of implementation, in addition to more general goals and objectives. The actual details of implementation and any modifications, improvements and departures from schedules are fully described in the annual reports. The co-licensees provide draft versions of the annual reports to agency representatives and hold occasional meetings to keep the agencies apprised of progress on the WHMP and seek concurrence.

3.0 METHODS: DESCRIPTION OF DATABASES AND OTHER INFORMATION SOURCES

District staff acquired reports of technical studies, journal articles, management plans, guidelines for land managers, regulatory documents, presentations at workshops, meetings and informal exchanges with other scientists, and many other information sources over the years that were relevant to the ongoing implementation of the WHMP. Information obtained from some of these resources has become dated or has been superseded over time, but much of the information in the Jackson Project wildlife library was still highly relevant to the review of the WHMP. Some of the data and observations cited in this report were obtained by District staff in the course of implementing the WHMP, for example, data on wildlife use of snag trees.

Review topics included:

- Old growth forests (including management of stands for old growth characteristics)
- Riparian habitat
- Streams, wetlands and buffer zones'
- Second growth forest/overstory management (including gaps and reserve green trees)
- Second growth forest/understory management
- Snags and gaps
- Coarse woody debris
- Right-of-way management
- Nest structures
- Deer forage

Staff also used on-line database searches to obtain and review the recent literature on wildlife habitat management in the Pacific Northwest. Databases included:

- ISIS
- BIOSIS
- Science Citation Index
- Wildlife & Ecology Studies
- Google Scholar
- Web of Science
- ProQuest
- Expanded Academic ASAP
- University of Washington main library catalog

Database searches involved selection of suitable on-line databases and appropriate keywords that would filter out documents that are not relevant to the objectives of Study Plan 6 (see Section 1.0). Keywords included management techniques (e.g. coarse woody debris), geographic filters (e.g. Washington), names of evaluation species (e.g. pileated

woodpecker), and relevant concepts (e.g. biodiversity). Other filters related to time frame (e.g. after 1990) or data type (e.g. journal article). Creating an appropriate set of keywords and filters for each management technique that captured relevant citations but not too many non-relevant citations usually required some experimentation. However, at some point repeated database searches on a given technique using various keywords and filters eventually produced the same sets of relevant documents, and we felt confident that we had obtained a comprehensive listing of available resources.

Citations that appeared relevant to the WHMP were entered into a WHMP reference database and the documents were reviewed by District staff, who classified each citation by management technique, summarized the key findings and assigned a rating of relevancy. The resulting annotated bibliography (Appendix 1) was distributed to reviewers in the resource agencies and the Tulalip Tribes in June 2007, with a request for comments and additional references, if appropriate. The District did not receive comments on the annotated bibliography. All citations are numbered in the bibliography and they are referenced in the report text as bolded numbers, e.g. **(282)**. References are arranged by number in Appendix 2 and by author in Appendix 3.

4.0 RESULTS: SYNTHESIS OF FINDINGS

This section reviews the current wildlife habitat management literature that appears to have application to the Jackson Project's WHMP. To be relevant a reference had to be:

1. related to the Pacific Northwest ecosystem, i.e. western Oregon, Washington, British Columbia;
2. currently applicable, preferably dated after 1990; and
3. consistent with the WHMP's stated goals and objectives, and relevant to the current management techniques. Review topics include: old growth forest; riparian habitat; streams; wetlands and buffer zones; second growth forest/overstory and understory management; snags; coarse woody debris; right-of-way vegetation management; nest structures; and deer forage.

The review included technical studies, review articles and management guidelines. Technical studies generally report the results of original research projects, and review articles compile and synthesize the results of many technical studies dealing with a particular topic; often the authors of these papers will offer management guidelines in addition to the research results. The literature review also includes guidelines that were prepared specifically for managers in an agency to implement, such as agency forest plans, or plans related to an endangered species.

The review included studies from parts of western Oregon and other locations that are dissimilar from conditions found within the Jackson Project. For example, other sites may differ significantly from WHMP lands in soil conditions and moisture regimes, which will affect responses of forest vegetation to different management procedures. Detailed comparisons of conditions on WHMP sites to sites reported in the literature should guide any application of specific management prescriptions for the Jackson Project.

4.1 Forest Vegetation Management

4.1.1 *Current research topics and trends*

Management of forest lands in the Pacific Northwest has traditionally focused on the production and regeneration of timber, but it has been recognized for several decades that managed forests have a simplified structure and species composition compared to forest stands that arise through natural disturbance (18, 56, 79, 215, 252, 319). Since the early 1990's scientists in public agencies, academic departments and industry have worked to develop alternatives to the traditional clearcut and commercial thinning methods used in PNW forestry (17, 18, 27, 28, 39, 77, 80, 115, 177, 214, 216, 217, 235, 251, 262, 263, 266, 281, 283, 307, 310, 314, 315, 316, 317, 318). District staff reviewed forest management guidelines and review articles, computer simulations of the effects of silvicultural practices, retrospective studies and several long-term experimental studies. The common theme of these studies is a desire to test whether silvicultural treatments can

provide or promote wildlife habitat value on managed stands and what the impacts would be on timber production. To accomplish this goal, forest researchers are looking for management techniques that accelerate the process of developing late-successional characteristics and shorten or eliminate the unproductive period (for most wildlife species) spent in the stem-exclusion stage (equivalent to the WHMP's closed canopy/sapling pole stage).

Review of these documents identified forest management methods that utilize:

1. traditional methods (clearcutting, reforestation with single species, silvicultural systems such as group selection, shelterwood cuts, and uniformly-dispersed commercial thinning),
2. modifications of traditional practices that add "legacy" elements such as retention or creation of large snags, coarse woody debris),
3. harvest with variable density thinning (VDT), and/or
4. harvest with green tree retention (GTR).

Technical studies examine how a wide variety of harvest and silvicultural alternatives can be manipulated to achieve targeted forest structure and species composition associated with high wildlife habitat values. In particular, green tree retention treatments and variable density thinning offer promise for wildlife habitat improvement, while still promoting timber production on second-growth timber stands. In the opinion of the District's reviewers, the studies and management guidelines noted in the following sections represent the best science currently available on forest vegetation management that is applicable to the WHMP.

4.1.2 Experimental studies

One of the most comprehensive recent experiments, the DEMO study (**214, 215, 235**), was set up in 6 locations in Oregon and Washington in the mid-1990s to evaluate the effects of green tree retention systems in managing Douglas-fir stands ranging from 65 – 170 years old. The treatments consist of 4 levels of retention (100%, i.e. no harvest, 75%, 40% and 15%) with dispersed or aggregated patterns. Additional snag trees were created on treatment units, pre-existing CWD was retained, and harvested stands were replanted to achieve a minimum stocking level of 312 trees per hectare (tph). A number of response variables will be sampled over the life of the project, including effects on overstory and understory structure and composition, and amphibian, small mammal, bat, and breeding bird populations.

The Forest Ecosystem Study (**318, 317**) in Washington tests whether development of late-successional forest attributes such as high plant species diversity, spatial heterogeneity in the understory, and vertical foliage diversity can be accelerated through variable density thinning with multiple entries into the stand.

The Westside Silvicultural Option Team of the US Forest Service's Pacific Northwest Research Station has set up several studies that will focus on the major stages of managed stands from early development (pre-commercial thinning), midrotation (commercial thinning) and regeneration harvest **(263)**. Study goals for early stands are to test how 5 silvicultural treatments may induce variation in tree species composition and stand structure, and how this affects plant and animal populations. Treatments include control plots; thinning with uniform tree spacing with and without interplanting of red alder, western hemlock and western red cedar; and variable density thinning with and without interplanting.

The Olympic Habitat Development Study **(263, 310)** evaluates the use of VDT to accelerate development of structural complexity in 35- to 70-year-old stands, and the associated development of plant and animal communities characteristic of late-successional forests. The thinning prescription involves “skips”, or untreated patches and gaps (stand openings) embedded in a thinned matrix. Skips are used to preserve large existing snags, and gaps include existing root-rot pockets. The matrix, which covers 75% of the treatment area, is thinned from below by removing 25% of basal area. Response variables include tree damage and mortality, tree growth, understory development, and surveys of small mammals and arboreal rodents.

The Capitol Forest study **(263, 316)** compares regeneration harvest methods. Treatments include clearcutting, two-age overstory retention, small patch cutting on a 15-year cycle, group selection, and an extended rotation with commercial thinning. Monitoring includes residual tree growth, damage and mortality, stand development and yields, costs of harvesting, harvest production, soil disturbance, and songbird populations. The STEMS project in British Columbia **(315)** is patterned after the Capitol Forest study.

Weyerhaeuser's British Columbia “Coast Forest Strategy” **(314)** was initiated in 2001 to test the use of VDT to enhance structural diversity. The experimental design tests the effects of various levels of group retention, dispersed retention, group size, and group removal on long and short cutting cycles. Response variables that will be monitored include live trees, snags, CWD, shrub and herbaceous layers, selected wildlife species, growth and yield, and windthrow damage.

Most of these recent experimental studies have produced some early results, mentioned in section 4.1.5, but long-term monitoring may be required to determine how effective the treatments are in achieving study goals.

4.1.3 *Retrospective studies*

Retrospective studies yielded useful results **(174, 203, 205, 213, 219, 235, 265)** on the effects of earlier silvicultural treatments on forest structure and composition, although they are limited in their application to the WHMP in some cases because previous treatments seldom focused on wildlife habitat improvement.

4.1.4 Computer studies

Computer simulations have provided useful predictions of the outcomes of various silvicultural alternatives (39, 177, 218, 262, 266, 281). Most of these studies, described in Section 4.1.5, predict overstory structure and density, timber volume, revenues and costs, and some also predict understory characteristics, under a variety of silvicultural treatments.

4.1.5 Key results of research studies

Some key results of the recent research include:

1. Promotion of multiple canopy layers, canopy tree structural diversity, and canopy and sub-canopy species diversity.

Management guidelines recommend canopy thinning in dense second-growth stands to promote old-forest structure (245). At the stand level, thinning reduces competition for light, water and nutrients, thereby increasing the growth of overstory trees and the abundance of understory plants. A major response of individual trees to thinning is increase in crown size. Tree crown height increases as lower branches survive and height growth continues. As crown length increases, stem diameter increases on the lower part of the stem: the tree's stem becomes more tapered and resistant to windthrow or stem breakage. An increase in diameter may occur within 3 to 5 yrs. Epicormic branching in Douglas-fir produces fan-like branches used for roosting by birds and rodents.

Key structural features that should be promoted for wildlife in managed stands: large trees, especially those with large limbs, large-diameter logs and snags, hardwood trees, understory vegetation diversity (244).

Thinning younger stands can accelerate development of late-successional stands (large trees, snags and woody debris, a multi-layered and spatially heterogeneous canopy and a high diversity of plant species). In the process of thinning, uncommon tree species should be retained; and conifer density should be reduced around hardwoods to maintain full vigorous hardwood crowns. Guidelines recommend heavy thinning around 0.25 to 0.6-ac patches of hardwoods (245). Seedbeds for establishment of understory plants should be created through limited disturbance to the forest floor. Shrub and hardwood density may require control if understory competition becomes excessive. Some trees or parts of stands should be managed at low density in order to provide space, maintain large crowns and encourage rapid diameter growth. Conversely, some patches should have relatively dense overstories to promote certain late-seral herbaceous species. Thinning can be used to promote patches of regeneration, resulting in multi-story stands, and some trees should be allocated for production of snags and CWD (106, 245).

A computer simulation (262) identified 2 general thinning strategies that promoted late-successional attributes: (1) Thin to create open canopy at age 40 by removing 80% of original density, intensively thin at age 60 (to increase growing space in the now-densely stocked tree understory), and limited or no thinning in the last entry at age 80 (preserves existing vertical structure and species diversity). Several thinning intensities achieved

late-successional criteria by age 117-120 yrs. (2) Alternatively retain more than 40% of original overstory density at 40 yr and thin to 99 tph at 60 yr, and 186 tph in 3rd entry. Compared to not thinning at all, these thinning strategies accelerated the development of late-successional criteria by about 100 yrs. Thus, creating a relatively sparse overstory and managing the tree understory to optimize vertical stratification were key to producing late-successional stand structure. Different thinning regimes achieved the desired result.

Decisions on how to implement these strategies must consider the likelihood of windthrow and the desired long-term stand conditions. Rapid development of an attribute will not necessarily produce the highest levels of the attribute over the entire rotation. E.g. relatively lower densities of shade-tolerant stems, lower Douglas-fir basal area, lower habitat diversity and fewer snags and logs over the rotation may accompany the fast attainment of late-successional characteristics. The recommended approach uses a variety of treatments with multiple goals.

These thinning strategies limited recruitment rate of dead wood and artificial snag, and log-creation was required to reach desired thresholds.

Aggregated green tree retention is thought to be more effective at maintaining a broad array of structural elements, such as multiple canopy layers and understory vegetation. Intact patches of habitat act as refugia for organisms that will recolonize the harvest unit **(235)**. One study **(43)** cited the following recommendation for forest matrix lands covered by the Northwest Forest Plan **(285)**: retain 15% of the harvest area as green tree reserves, 70% of which should be clumps 0.2 to 1.0 ha in size, and the remainder dispersed either individually or in small clumps. These clumps should be comprised of the largest, oldest, decadent or leaning trees and hard snags occurring within the unit. Snag management would primarily occur within these GTR areas.

Variable density thinning is expected to accelerate canopy structural diversification **(77, 128, 310, 318)**. Crown-class differentiation may be the factor in forest development that is most amenable to management: (1) species composition can be determined managerially at stand initiation by legacy retention, planting and pre-commercial thinning, (2) management of stem density and growth rates is well founded, and (3) spacing can be varied tree to tree or patch to patch within stands **(318)**. Determining the number of trees to remove can be based on relative density measurements (RD, the actual density of trees relative to the theoretical maximum density possible for the site, on a scale of 0 to 100); recommendations included relative densities of 5 to 35 in a ratio of 2:1 over the stand **(318)**, and 20-70 **(128)**. Multiple thinning entries may be required to prevent canopy closure.

Silvicultural alternatives that emulate natural disturbances can produce uneven-age stands with higher structural diversity, including small group selection or individual tree selection, management that favors shade-tolerant species, and variable density planting **(17, 177, 245, 263, 283)**. GTR up to 40 tph appears to promote the development of a shade-tolerant understory without eliminating Douglas-fir from the stand **(219)**.

Retention of hardwoods and cedar is recommended because they are preferred by many species of cavity-nesting birds **(66, 244, 317)**. Planting of white pine and grand fir on suitable sites is also recommended, as they are highly preferred as nest sites when available **(66, 101)**.

Large trees, e.g. wolf trees, and remnant old growth trees, if well dispersed, can facilitate movement of forest interior wildlife species in areas that are otherwise unsuitable (i.e. harvested). Options for recruiting, developing and maintaining large trees include retaining green trees at harvest, and growing them at reduced stand density to provide growing space for larger limbs and deeper crowns **(244)**.

A review of wildlife responses to thinning young forests recommends thinning stands prior to 50 years after stand initiation to promote large live trees, trees with large crowns and branches, and multilayered canopies. Other desirable features include retention of large snags and CWD **(80)**.

Thinning stands before age 15 will encourage wind firmness and large crowns. Thinning dense stands in the stem exclusion stage increases the potential for windthrow, although thinning in stages can reduce the problem. Repeated thinning in later stages (age 70 to 100) may lead to stands resembling shelterwood, with an understory beneath a few large trees **(80)**.

Thinning recommendations from a review article **(80)** target certain relative densities. At $RD > 55$, suppression mortality occurs. Stands are typically thinned to RD 35 for timber production, and allowed to grow back to RD 55 before final harvest or subsequent thinning. Thinning to $>RD\ 35$ is a light thinning, however; thinning to $RD < 25$ (heavy thinning) and thinning again when the stand grows to RD 45 promotes understory development and vertical diversity. The article predicts that stands can have about 20 healthy 50-inch dbh trees per acre; stands at this density are likely to have a rich understory.

2. Promotion of understory herb and shrub layer recovery after harvest, and development of these vegetation layers through the rotation.

According to a review article, the conventional wisdom regarding understory vegetation makes the following points:

- Understory vegetation increases dramatically immediately after logging but decreases to near-zero as stands attain conifer canopy closure.
- Depauperate understories may persist for >100 yrs.
- Understory response to thinning of even-aged stands is mainly by dominant shrubs and is short-lived.
- Response by herbs, especially forbs, is slight.
- Western hemlock is a potentially long-lived, second-layer, understory dominant in stands thinned to wide spacing **(264)**.

The review article qualifies these findings: Commercial thinning of older even-age stands may result in much greater understory biomass, including forbs, but time requirements

might be longer than previously thought. Plant species differ in their ability to germinate and establish, and in their growth rates in relation to light; therefore, understory species' response to thinning may be the result of differential time lags in response to light, differential species productivity in relation to light, and dynamics of change in the understory light environment. Extrapolation of data from small scales of research plots to large scales of timber-management stands tends to greatly overestimate stand homogeneity, and underestimate understory biomass of even-aged conifer stands **(264)**.

In a study of thinned and unthinned second-growth Douglas-fir stands, total herb cover and species richness in the thinned stands was greater than in the unthinned stands. Part of this was caused by exotic species in thinned stands, but these stands also had more grass species and nitrogen-fixing species **(275)**.

Standard commercial thinning resulted in initial declines in bryophytes, tall shrubs and low shrubs followed by subsequent recovery and growth. The addition of gaps generated plant assemblages that differed across the gradient from the gap to the thinned forest matrix. Thinning with gaps can hasten late-successional understory development **(48)**.

The response of understory vegetation to thinning of young stands depends on initial stand density, species composition, vigor of understory plants before thinning, seed sources and bud banks, thinning intensity, and soil disturbance, however, sunlight is the primary factor. Thinning to moderate densities in closed-canopy stands stimulates modest and temporary development of understory vegetation; heavier thinning or multiple entries favors the establishment and growth of conifer seedlings, shrubs and hardwoods **(80)**.

Guidelines for managing for biodiversity in young conifer forests call for combinations of relatively heavy thinnings, VDT and/or multiple thinning entries to retain and promote understory and midstory vegetation **(17, 109, 115)**. Thinning combined with moderate soil disturbance creates germination substrates for seedling regeneration of woody and herbaceous species. Thinning Douglas-fir stands on some Oregon sites is followed by increases in seedling germination of salal, vine maple, huckleberry, tanoak, bigleaf maple, red alder, salmonberry, Pacific madrone. However, development of shrub cover and wildlife forage occurs much more rapidly from sprouts, which is the preferred method of regeneration **(245)**.

A field study **(203)** examined the response of understory plant diversity 16 months after a green tree retention (GTR) harvest (retaining 27 tph) on three sites in Oregon and Washington. Adjacent treatment areas included a clearcut and an uncut control stand. Herb and shrub species richness and evenness were significantly higher in the GTR cut than in the other 2 treatments. Although 68% of understory cover in the GTR was invasive species (compared to 84% for the clearcut and 0% for the intact forest), the GTR retained more species and cover of shade-tolerant plants. The retention of trees on the harvest site may provide greater microsite or microclimate variability than would be present in a clearcut. Most of the invasive species are shade-intolerant, and will not persist with seral development. The number and constancy of shade-tolerant species

therefore provides some indication of the potential future understory diversity on GTR units as light levels decrease with canopy closure.

Baseline forest vegetation measurements acquired for the DEMO study **(214)** were used to evaluate relationships between canopy characteristics and shrub layers **(301)**. Overstory variables explained >50% of variation in total shrub cover and about 50% of the variation in vine maple, the most common species. Stronger relationships found between each of 3 functional groups of herb species ("release" herbs capable of rapid expansion, late-seral herbs, and dominant herbs). Results represent both direct resource limitations and time-dependent responses for which overstory characteristics may be surrogates. Release herbs were positively correlated with variables that peak during early to mid-succession. Dominant herb species response was weakly correlated with overstory variables: these species are able to thrive and dominate the herb layer in a variety of forest conditions. Late-seral herbs, total shrubs and vine maple were linked both to changes in available resources and to the passage of time. The models worked best at predicting shrub cover and late-seral herb cover. They should be applicable to low and mid-elevation forests in western hemlock and Pacific silver fir zones.

A computer simulation **(218)** of future stand structure and composition following the green-tree retention treatments of the DEMO study **(214)** examined the likely response of understory vegetation. At 40% retention level, the well-distributed shade of dispersed trees limits growth/development of the understory compared to uncut aggregates of the same basal area. At 15% retention, understory production is roughly equivalent for both aggregated and dispersed retention.

Following the green tree retention treatments of the DEMO study, most groups of forest understory plants declined in abundance and richness more at the 15% retention level than at 40% retention. Changes within the 1-ha aggregates were small on average, and declines in adjacent harvest areas were greater than those in the corresponding dispersed treatments. Two years post-treatment, aggregates had gained an average of 2 forest species (vs. a loss of 2 in adjacent harvested areas) and less than 1 early-seral species (vs. a gain of 9 in adjacent harvest areas). The 1-ha aggregates supported populations of late-seral species that disappeared from or declined in harvested areas, although forest herbs declined on the edges of the aggregates **(226)**. Late-seral herbs more frequently were extirpated from harvested plots in the aggregated treatments than from plots in the dispersed treatments **(214, 216, 217)**. Separating the effects of logging disturbance from effects of green tree retention (short-term vs. long-term effects) is an important focus of research. Short-term responses to treatment likely are driven by variation in the distribution and intensity of harvest disturbance. Longer-term trends are expected to reflect the effects of contrasting patterns of canopy retention **(215, 216, 217)**.

The Olympic Habitat Development Study **(263, 310)** evaluates the response of understory to variable density thinning involving untreated patches and gaps embedded in a thinned matrix. Understory vegetation responded to thinning with increased cover and number of herb species in thinned areas and created gaps. Introduced species were most prevalent in the thinned and gap sub treatments vs. untreated patches or control plots. All introduced species were herbaceous except for Himalayan blackberry. Shrub response was slower

than herb response and more variable. Shrubs previously present on stands persisted despite damage, and are slowly increasing. Cover of mosses and liverworts was greatest in undisturbed areas.

3. Overstory response to alternate silvicultural treatment; improvement of post-harvest residual (green tree) survival.

A retrospective study (**322**) of Douglas-fir stands that had been thinned for timber production 10-24 years earlier showed that thinning young Douglas-fir stands will hasten the development of multistory stands by recruitment of conifer regeneration in the understory as well as by enabling the survival of small overstory trees and growth of advanced understory regeneration. Thinning will also help develop the shrub layer by increasing tall shrub stem density and cover of some low shrubs. At the time of this study, thinned stands had a wide range of density (mean 173 tpa, range 72-346), basal area (mean m²/ac, range 20-58) and relative density (mean 37, range 23-60).

A field study (**203**) examined basal area growth of retention trees six years after a green tree retention harvest (retaining 27 tph). Adjacent treatment areas included a clearcut, and uncut 65 year-old control stand. The average response for all GTR stands six years after harvest was a 15% reduction in increment growth compared to the control stands. This unexpected result may be explained by several hypotheses involving thinning shock and the effects of tree size.

A retrospective study (**299**) assessed growth, condition and mortality of residual trees 10 yr after harvest in 85 to 125-y.o. Douglas-fir stands in Oregon coast range foothills. Three silvicultural treatments: a group-selection cut that removed 33% of entire stand volume as patches approx. 0.2-0.8 ha; a two-story regeneration harvest that removed 75% of volume and left 20-30 residual trees/ha; and clearcuts with 1.2 residual trees/ha. After 10 years there was little differentiation in the characteristics of residual trees: tree basal area, diameter and height growth, and crown width and fullness did not differ between treatments. Live crown ratio was largest in clearcuts (0.74), and the proportion of trees with epicormic branching was highest in 2-story stands (35%). 45% of trees had more basal area growth in the decade after harvest than in the previous decade. Residual green trees in clearcuts and group-selection stands experienced the highest and lowest percentage mortality, (30.6% vs. 0.2%), respectively.

Western hemlock stands were studied retrospectively: 70-110 year-old stands (regeneration) and 70-110 year-old stands with an overstory of large trees that were 200+ years old (remnants). 15 remnant tph can be retained following harvest without significant reductions in regeneration growth, and total stand basal area (BA) remained fairly constant across remnant densities. At <45 remnant tph, regeneration BA declined related to the combined effects of shading (or other suppressive effects) and space occupancy by remnants. Part of the effect of remnants on regeneration, results from the remnants' occupation of space, which makes that space unavailable for regeneration. BA of western hemlock regeneration increased as that of Douglas-fir decreased. Results differ from simulation models (Hansen et al 1995), which predicted reductions in regeneration growth and total stand BA at lower levels of retention. Silvicultural

techniques could moderate the decline in both Douglas-fir regeneration BA and regeneration BA across all species with increasing remnant density. Douglas-fir could be planted in more open areas of a site harvested with green tree retention, while regeneration of western hemlock or other shade-tolerant species could be facilitated in areas with more canopy cover. Remnant density was not related to tree-species diversity in the regeneration **(265)**.

Tree mortality in the DEMO **(214)** green tree retention experiments was significantly greater at 15% than at 40% retention **(216, 217)**. At both levels of retention, aggregation of trees significantly reduced mortality. Mortality of co-dominants was greater at lower levels of retention, especially in dispersed treatments. Suppressed trees had higher mortality in dispersed than in aggregated treatments. Wind damage was particularly common at the 15% retention level. Short-term, forest aggregates of 1-ha are fairly stable. At low retention levels, dispersed patterns are susceptible to logging and wind damage, leading at increased mortality **(216, 217)**.

A computer simulation **(218)** of future stand structure and composition following the green-tree retention treatments of the DEMO study **(214)** projected that at 40% retention level, overstory production for the 100-year simulation period is comparable between the dispersed and aggregated treatments. At 15% retention, with the significant spacing given to overstory trees in the dispersed pattern, overstory production is more than twice the amount observed in the aggregated pattern.

Results of the Young Stand Thinning and Diversity Study **(48, 321)**, which applied 3 thinning treatments to 30- to 50-year old Douglas-fir stands, including a typical commercial thin, a heavy thin, and a commercial thin with 0.2 ha gaps. Five to seven years following thinning, canopy cover of the light thin no longer differed from the control, while canopies of other thinned treatments remained more open than the control. Most species had no difference in mortality rates in the treatment areas, and the highest mortality occurred in uncut controls. Thinning decreased density-related mortality of Douglas-fir, and mortality was low for nondominant overstory trees. Growing conditions for residual trees were most improved by heavy thinning to 125 tpa. Vertical structure did not differentiate during the 2 to 4 years following harvest.

The STEMS experiment on Vancouver Island **(315)** has provided some preliminary results of treatments similar to those of the Capitol Forest Study **(263, 316)**. These include aggregated retention (residuals left in groups ranging from 0.02 to 1.2 ha), dispersed retention (40 tph), group selection (13% of area cut every 10 years in patches 0.06 to 0.5 ha), patch cut (13% of area cut every 10 years in patches 0.55 -2.0 ha), clearcut with reserves, and extended rotation with commercial thinning (which left 350 tph evenly dispersed). Tree damage was highest in the dispersed retention block (17%), primarily caused by forwarding activities, and in the extended rotation with commercial thinning block (15%), where yarded stems rubbed against the residual trees. The aggregate retention, group selection and patch cut treatments had the lowest damage. Windthrow was highest in the dispersed retention treatment, and was lower in the aggregate retention. The other treatments experienced little windthrow.

4. Canopy gap management, conifer regeneration and development; promotion of shade-tolerant conifers and hardwoods.

Establishing Understory Conifers: If the goal is to manage understory conifers as a second story for habitat (and ultimately crop trees), guidelines recommend relatively low overstory density. Overstory density should not exceed 20% of full stocking **(245)**. Reduction in overstory density can result in excessive conifer regeneration. Managers can reduce regeneration via moderate soil disturbance during timber harvest or a subsequent pre-commercial thinning

Promoting Understory Vegetation: Thinning combined with moderate soil disturbance creates germination substrates for seedling regeneration of woody and herbaceous species. Thinning Douglas-fir stands is followed by increases in seedling germination of salal, vine maple, huckleberry, tanoak, bigleaf maple, red alder, salmonberry, Pacific madrone. However, development of shrub cover and wildlife forage occurs much more rapidly from sprouts, which is the preferred method of regeneration **(245)**.

Guidelines state that floristic diversity, in particular the presence of shrubs and hardwood trees, is especially important for wildlife diversity **(244)**. Literature shows consistent patterns of positive correlations between birds and abundance and distribution of hardwoods in conifer forests. "Hardwoods may be preferred by many species [of cavity-nesting birds and mammals] because wood properties and decay patterns often result in softened heartwood that is easily excavated, while the sapwood remains unaffected by decay...In contrast, sapwood of Douglas-fir snags often decays by the time heartwood is sufficiently softened for cavity excavation. Because of these differences, hardwoods can provide suitable cavity sites at relatively smaller diameters than conifers" **(206)**. Management of hardwoods should begin early in stand development. Controlling density at an early age, before canopy closure, can help to maintain diverse stand structure throughout the life of a stand **(252)**. Although shrubs may dominate early succession, it is unlikely that clear-cutting can be used to immediately create quality habitat for shrub-associated wildlife species.

Western red cedar and Douglas-fir were planted together after applying 7 site-preparation methods at one site in the Oregon Coast Ranges: (1) no site prep, (2) spot-clear in a 1.2 m radius around each tree seedling, (3) spray with glyphosate, (4) broadcast burn, (5) slash and burn, (6) spray and burn, (7) burn and sow grass seed. Survival of red cedar was markedly less than Douglas-fir due to browsing. Site preparation by broadcast burning generally yielded the best results, but sowing grass after broadcast burning produced Douglas-fir responses similar to those for no site prep. Where grass was sown, herbaceous cover was more abundant and tall, and development of red alder was delayed **(255)**.

Canopy gaps are naturally occurring phenomena in forest ecosystems, caused by various agents ranging from individual trees dying from suppression, disease or breakage, to multiple or many stems dying from wind or snow damage, disease, insect outbreak or fire. Heterogeneity and habitat complexity resulting from canopy gaps can lead to increases in the number and diversity of plant and animal species. Multiple canopy

layers, increased tree species richness and increased herb and shrub cover can also result from increased light input resulting from creation of canopy gaps.

Canopy gaps can be created (or natural gaps enlarged) using snag tree creation in place of natural mortality factors. Size, aspect and orientation of gaps all play important roles in determining the effect on understory vegetation as well as regeneration by tree species. Gaps that are not large enough will not allow adequate light input to encourage shrub growth, and may instead be filled in by shade-tolerant hemlock seedlings, which could actually lead to a decrease in herb and shrub production, thereby reducing the resources required by small mammals (171, 292). Experiments on both natural and created gaps found that time since gap initiation was also important (25), since shade tolerant conifer species were able to establish on the forest floor 25 years after gap creation (174). In another study, however, gaps determined to be over 50 years old were still devoid of seedlings (26). Specific gap and site characteristics will determine the degree to which regeneration occurs. Each tree species has specific requirements that must be met for successful seedling establishment; Douglas-fir reproduces best on mineral soil in high-light conditions, but can germinate in shade or become established on intact forest floor (25); hemlock is highly shade tolerant, but is sensitive to competition (26) and tends to establish best on elevated surfaces such as highly decomposed Douglas-fir logs (108); and silver fir is also shade tolerant, but also sensitive to both understory and overstory canopy density (26).

On stands such as those at Spada Lake, where even-aged forests consisting primarily of 40-year old hemlock and silver fir dominate, and the upper canopy is very dense and inter-connected, light input to the forest floor is very low, likely less than 5% of full sun (107). However, the effect of increased light input resulting from gap formation is not confined to the boundaries of the gap itself (104, 110). Due to the high sun angles experienced at our northern latitude, the effect of increased light input to the forest floor may be seen up to 20 meters north of the actual gap (71, 110, 231, 302). Although some studies have found no relationship between canopy openings and seedling regeneration on the forest floor (26, 302), most researchers consider gaps to be required to allow silver fir and hemlock to reach the main canopy (108, 302).

Gap size appears to be very important in determining the type of regeneration that occurs. In gaps with a diameter equal to 0.2 or 0.4 times the average canopy height, regeneration of hemlock and silver fir was greatest (26). Gaps with diameters equal to 1.0 times the average canopy height had less seedling establishment (26), due to dramatic increases in direct light levels and soil temperatures along the northern edge of the gaps (110). Douglas-fir seedling growth was greatest in the largest gaps, and hemlock growth increased with increasing gap size, silver fir showed the least response to gap size (25), however, the advantage the hemlock incurs from growing on elevated structures appears to decrease with increasing gap size (26).

The response of existing vegetation within gaps is a result of gap size and shape, fine scale environmental factors (26, 239), and the particular hold-over plant species' survival tactics. Hemlock and silver fir can survive for decades with little growth in shaded

environments, resuming growth following canopy disturbance **(25)**. Woody perennials such as huckleberry have the ability to store resources for long periods of time, and persist in a juvenile prostrate form until adequate light resources are available **(105, 109)**. Salmonberry and salal were noted to increase in the understory as canopy cover decreased, and were shaded out when cover reached 85% **(239)**.

The species of canopy tree also impacts the type and amount of understory. A hemlock over story, with crowns that are denser than that of Douglas- or silver fir **(71)** can have strong negative effects on understory **(105)**. Percent frequency, cover and species richness of many common understory species are reduced under a closed canopy of hemlock, versus Douglas-fir or canopy openings **(105)**.

Creation of canopy gaps can be used to increase the heterogeneity that is lacking in closed canopy stands, thereby increasing the amount of desirable herbs and shrubs on the forest floor and encouraging a secondary canopy layer to develop **(25)**. Within mature stands, the creation of multiple canopy gaps is likely to increase the abundance of closed-canopy species **(171)**. However, excessive fragmentation can reduce reproduction rates of interior forest nesting bird species at both stand and regional scales **(138)**. Creation of gaps 30-50 meters in diameter may increase populations of small mammals, which in turn feed raptors and small carnivores. These small mammals may also help to reduce seedling regeneration within the gap **(292)**. This size of canopy gap is also likely to create a below-ground gap, by eliminating the interconnected web of roots of the trees that are killed. In turn, this allows more resources to be available for shrubs and herbs, thereby leading to an increase in flower/fruit production **(109)**.

Five years after experimental thinning at 3 levels (199 tpa, 60 tpa, 30 tpa) with underplanting produced the following results: growth of Douglas-fir and western hemlock seedlings was greatest in the heaviest thinnings. Sitka spruce, western red cedar, grand fir and red alder seedlings showed greater growth in the 60 tpa stands. Abundance and vigor of natural regeneration conifers increased with thinning intensity **(77)**.

Twelve years following a clearcut harvest with reserve trees on a stand that had previously been subject to heavy and light thinning in two different sections, seedling density (99% Douglas-fir) was somewhat clumped, but 98% of 5x5 m grid cells had at least one conifer seedling. Both seedling density and seedling size within the drip line of reserved tree crowns were less than in the rest of the area. In the half of the study plot that had been lightly thinned twice, only 14% of the seedlings were >0.5 m tall; however, 41% of the seedlings were >0.5 m in the block that had been thinned more heavily. There was no difference between the thinning blocks in the ages of seedlings <0.5 m tall (mean age 5 yr) **(280)**.

This example of clearcutting with reserve trees resulted in reasonable survival of the overstory trees and adequate stocking but slow growth rates in the naturally regenerated Douglas-fir. Heavier thinning before harvest was associated with more advance regeneration, more shrub cover, and less windthrow of reserved trees than in the more

lightly thinned block. If an abundance of tree species other than Douglas-fir was desired on this site, interplanting would be required **(280)**.

Results of studies of small gaps: Gap sizes were determined by gap diameter:tree height ratios, and were classified as 0.2, 0.4, 0.6 and 1.0. Gap size was marginally significant for seedling establishment, but seedling size increased with gap size. Silver fir and hemlock seedling establishment was greater in the smaller gaps; hemlock establishment in the 1.0 gaps was significantly lower than other species. Douglas-fir survived best in shady portions of the sunniest gap area (south edge) and in the more open portions of the smaller, darker gaps (north edge) **(26)**.

5. Impacts of silvicultural alternatives on wildlife populations

This section reviews surveys of breeding and wintering bird populations **(61, 128, 176, 190, 258, 267, 286, 300, 303, 307)**, amphibian populations **(114, 237)**, small mammals **(52, 61, 151, 166, 169, 171, 237, 256, 272, 279, 308)** and other species of interest, such as cavity-nesting birds **(19, 43, 98, 122, 139, 175, 236)** and the northern spotted owl **(39, 285)**.

Bird Populations:

In general, thinning densely stocked second growth conifer stands enhances habitat suitability for many bird species, consistent with what is known about their natural history, but some unthinned patches and stands should be retained to provide refugia for species that are impacted by thinning **(286)**. The following results are particularly noteworthy for the District's evaluation of the WHMP:

Studies of breeding and wintering birds in commercially thinned and unthinned second-growth Douglas-fir stands in the Oregon Coast Ranges **(128)** found the abundance of many breeding birds was consistently greater in thinned stands, while a few species favored unthinned stands. Bird species richness was correlated with structural features: habitat patchiness and densities of hardwoods, snags and conifers. For bird species associated with older forests, management recommendations included commercial thinning from below, snag creation, and promotion of hardwoods and shrub cover. Variable relative tree densities (from 0.2 – 0.7) across a stand will favor a broad array of forest bird species.

Studies of resident birds in the Oregon Coast Range **(258, 300)** looked at the results of 3 silvicultural treatments, including clearcut with 1.2 green trees/ha retained, small-patch (0.2-ha) group-selection (1/3 volume removed), and two-story cut (3/4 volume removed with 20-30 trees/ha retained dispersed through the stand). Total bird abundance was highest in small-patch stands, and lowest in modified clearcuts, species richness was highest in small-patch stands, and lowest in uncut and clearcut stands. Bird species responded differently to the treatments, but in general treatments that retain structural and compositional vegetation complexity, or that develop late-successional characteristics more quickly, will be used by more bird species than traditional clearcut treatments.

A comparison of commercial thinning and no thinning in naturally-regenerated hemlock stands in Pierce Co., WA (176) showed that reducing canopy cover from 89% to 73% reduced the inventory of large snags, increased understory forb, grass and conifer seedling density, and populations of several bird species responded positively. Management recommendations included promoting a mosaic of stand conditions (age classes and silvicultural treatments) to satisfy the needs of most species.

Studies of bird population responses to two intensities of partial cutting (30% volume removal and 60% volume removal), and clearcuts in British Columbia (61) showed that bird communities in the partial cuts were similar to uncut stands, but individual species responded differently to the level of canopy removal. This study also concluded that clearcuts can be enhanced for birds by leaving scattered individual mature trees or patches of trees.

A management guide to breeding bird habitat in young conifer stands (307) provides many useful recommendations, summarized in Table 4.1.5-1. Planning forest stand conditions requires strategizing among desired habitat features and bird species. Managers may emphasize habitat needs of special status birds, habitat diversity, or bird species richness. A sound strategy combines these approaches. One can manage for species diversity at larger scales, and emphasize habitat conditions that meet the more specialized needs of priority species at smaller scales. Planning for old forest habitat requires that we manage tree density early in stand development, before canopy closure to maintain a diverse stand structure throughout the life of the stand. This management guide includes a useful appendix listing relationships between thinning and abundance of individual bird species.

Table 4.1.5-1. Desired habitat features for breeding birds in young conifer forests in the Northern Pacific Rainforest Bird Conservation Region, and management activities that may be used at various stages of stand development to achieve those features (from Altman & Hagar. 2007. Rainforest Birds: A Land Manager's Guide to Breeding Bird Habitat in Young Conifer Forests in the Pacific Northwest (307).

Desired Features	Early Successional Management	Mid Successional Management	Examples of Bird Species to Benefit (successional stage) ¹
Large Conifer Trees	Retain existing large trees Establish stands at low densities (<500 trees per hectare [200/acre]) to maximize individual tree growth Thin to maintain growth rates	Thin to accelerate growth rates Use long rotations to maximize growth Recruit and maintain replacement large trees	Brown Creeper (mid); Chestnut-backed Chickadee (mid); Hermit Warbler (mid); Olive-sided Flycatcher (early)
Large Snags	Retain existing large snags Create snags through topping, girdling, etc. of residual green trees	Create snags through topping/girdling, etc. of residual green trees Use long rotations to maximize time for snags to develop	American Kestrel (early); Chestnut-backed Chickadee (mid); Pileated Woodpecker (mid); Purple Martin (early); Western Bluebird (early)

Desired Features	Early Successional Management	Mid Successional Management	Examples of Bird Species to Benefit (successional stage) ¹
Deciduous Trees	Retain existing deciduous trees Plant deciduous trees and manage for their survival Thin competing conifers to open the canopy and enhance deciduous tree development	Protect deciduous trees and patches when thinning conifers Thin competing conifers to open the canopy and enhance hardwood development	Black-throated Gray Warbler (mid); MacGillivray's Warbler (early); Pacific-slope Flycatcher (mid); Red-breasted Sapsucker (mid); Wilson's Warbler (early)
Berry and Nectar Producing Trees and Shrubs	Retain existing berry and nectar producing trees and shrubs Plant berry and nectar producing trees and shrubs and manage for their survival	Maintain low percent canopy cover for a light-rich environment Protect shrub patches when thinning	Band-tailed Pigeon (early and mid); Cedar Waxwing (early and mid); Rufous Hummingbird (early and mid)
Mixture of Tree Species	Retain a diversity of tree species Conduct mixed species plantings	Retain a diversity of species in thinning prescriptions	Band-tailed Pigeon (mid); Black-throated Gray Warbler (mid); Varied Thrush (mid)
Multi-layered Structure	Retain a mixture of leave tree and shrub species Maintain low percent canopy cover to encourage diverse understory Conduct mixed species plantings Cut some hardwoods to encourage sprouting	Thin to low relative densities Favor mid-story hardwoods in thinning prescriptions Use long rotations to maximize time for multi-layered structure to develop Protect pockets of natural regeneration Retain live trees at final entry to provide greater canopy layering in subsequent stands	Band-tailed Pigeon (mid); Red-breasted Sapsucker (mid); Varied Thrush (mid)
Old Shrubs	Retain and protect old shrubs Maintain low percent canopy cover to encourage understory development	Protect old shrubs during thinning Thin to low relative densities to maintain open canopy	MacGillivray's Warbler (early and mid); Rufous Hummingbird (early and mid); Swainson's Thrush (early and mid); Wilson's Warbler (early and mid)
Shrub Patches	Retain and protect shrub patches Thin to encourage understory development Cut some hardwoods to encourage sprouting	Protect shrub patches during thinning Thin to low relative densities to maintain open canopy	Blue (Sooty) Grouse (early and mid); MacGillivray's Warbler (early and mid)
Large Wood Debris on Forest Floor	Retain and protect existing down logs, especially large ones Recruit live trees for large down logs	Thin to accelerate growth, then create logs Use long rotations to maximize time for trees to grow; Fell and leave some trees as logs	Blue (Sooty) Grouse (early and mid); Pileated Woodpecker (early and mid); Winter Wren (early and mid)

Desired Features	Early Successional Management	Mid Successional Management	Examples of Bird Species to Benefit (successional stage) ¹
Variation in Overstory and Understory Cover (patchiness and edges)	Thin to encourage diversity in the overstory and understory Conduct variable density planting of conifer and hardwood species	Conduct variable density and variable spaced thinning Conduct single tree and group selection harvests	Blue (Sooty) Grouse (early and mid); Olive-sided Flycatcher (early and mid)

¹ The emphasis is on birds identified in Table 4 because of their recognition as priority or focal by Partners in Flight at different levels (i.e., state/provincial, regional, international).

The DEMO study (**214, 237**) has produced several hypotheses relating bird populations and green tree retention: (1) Abundance of canopy-dwelling birds will decline with decreasing levels of tree retention; aggregation of retention will reduce this effect; (2) Abundance of birds associated with understory vegetation will decline with decreasing levels of tree retention in the short term (<5 yr); abundances will increase in the longer term. Aggregation of retention will ameliorate the effects of decreasing retention; and (3) Primary and secondary cavity nesting birds will decline with decreasing levels of tree retention and by dispersing the pattern of retention.

Amphibian Populations:

District review found limited information on amphibian responses to silvicultural alternatives. The DEMO study (**214, 320**) has produced some results related to green tree retention harvests: For the 4 most abundantly captured species: ensatina, western red-backed salamander, northwestern salamander, and rough-skinned newt, no trends were evident associated with the level and pattern of green tree retention two years after treatment. However, salamanders were encountered most frequently when CWD and herb cover were high. These structural features apparently are more important to salamanders than tree basal area. DEMO hypotheses relative to amphibians are: (1) Abundance of amphibians will decline with harvest intensity, and (2) Amphibians will persist in forest patches in aggregated retention units, but most species will decline in harvested areas within aggregated retention units and in dispersed retention units, and (3) Species richness of small terrestrial vertebrates is positively correlated with CWD volume (**208, 237**).

Small Mammal Populations:

Arboreal and semi-arboreal small mammals are consistently found in closed-canopy forest that has developed beyond the stem-exclusion stage, but these species can occupy younger stands with diverse understory composition and woody debris legacies (**202**). Terrestrial small mammals vary in their habitat preferences, and some are most abundant in early-successional communities and will increase following high-intensity disturbances, whereas others favor closed-canopy habitats. Clearcut logging produces unfavorable habitat for closed-canopy species, but providing CWD inputs can ameliorate the impact (**237**). The DEMO study (**214, 237**) has hypothesized that (1) Abundance of

arboreal rodents will decline with decreasing levels of green tree retention, although aggregation of retention will reduce this effect, (2) Terrestrial small mammals associated with closed canopy (post-stem-exclusion) forests will decline with increasing levels of disturbance regardless of retention pattern, and (3) Small mammal species associated with early-successional habitats, and habitat generalists, will increase or be unaffected by disturbance intensity. Effects of small experimental canopy gaps (approximately 0.4 ac in size) on small mammal abundance and diversity in the southern Washington Cascades were minor **(171)**.

The British Columbia study **(61)** also reported impacts of partial cutting on vole species. As with bird species in this study, vole species responded differently to the treatments. Red-backed voles responded favorably to light partial cutting (or no cutting), while other vole species and deer mice favored larger openings. By varying the intensity and spatial pattern (dispersed or clumped) of timber harvest within a stand, it may be possible to create the range of conditions favored by different guilds. The down side of the treatments was a loss of snag trees.

Thinned stands had 1.5 times the individual small mammals and 1.7 times the mammal biomass versus harvested stands with retained legacy trees (live trees, snags and CWD). Thinned stands showed a greater abundance, biomass and diversity of small mammals compared to legacy stands, but neither type of management supported the complete small-mammal community found in old growth forests **(256)**. The authors suggest that combining thinning and legacy retention could provide more benefits than either of the individual strategies.

6. Legacy features in managed forest stands

The District's review found a strong consensus that legacy features, such as snags, CWD, large decadent trees and trees with large branches must be retained and promoted on managed forest stands where structural complexity and wildlife habitat benefits are a management goal.

Management guidelines and review articles recommended conserving biological legacies during harvest and regeneration, including soil organic matter, litter, CWD, snags, forbs, shrubs and mycorrhizal fungi **(18, 27, 245, 283)**. Sites with mistletoe brooms provide nesting sites for spotted owls, marbled murrelets, squirrels, and other birds and small mammals **(230)**. If adequately dispersed, large trees in otherwise unsuitable (i.e. harvested) areas can facilitate movement of forest interior species. Options for recruiting, developing and maintaining large trees include retaining green trees at harvest, and growing them at reduced stand density to provide growing space for larger limbs and deeper crowns **(244)**.

7. Impacts of alternative silvicultural treatments on timber volume and revenues

Evaluation of timber-related goals was beyond the scope of this review; however, some of the technical papers we reviewed presented information on this topic. Computer simulations and retrospective studies provided information on growth and yield of experimental stands, and contrasted them with traditional forest management practices (203, 218, 246, 263, 265, 266, 281, 315). This topic would require additional review to evaluate what the differences might be between traditional management and silvicultural alternatives.

4.2 Snag Management

4.2.1 Field Studies and Management Guidelines

Current research regarding snag management includes determining appropriate targets for snag densities and sizes. WDFW's "SNAGS: Management Recommendations for Washington's Priority Habitats" (102) calls for using natural ecosystems as models for determining appropriate numbers and characteristics of snags. The authors note that "diverse, abundant and stable communities of snag-using species occur in unmanaged forests, particularly late-successional stands." Additionally, only old-growth stands were found to support 100% of the maximum potential population of primary cavity-nesters, thus using averages from those stand types would provide the greatest potential for retaining populations of snag dependent wildlife. The WHMP was expected to achieve this goal, aiming to "provide 100 percent of the snag needs of the primary and secondary cavity nesters common to the area" (14). Management goals aimed at providing less than this could contribute to a decline of the 56 cavity-dependent species, which may result in them being listed as threatened or endangered. An additional 46 species are known to use snags for some stage of life, ranging from breeding and foraging to nesting or roosting (102).

In Washington, 14 cavity-nesting species are classified by WDFW as Priority Species; the Northern Spotted Owl is listed as Endangered; the western gray squirrel is listed as Threatened, and the Pileated woodpecker (PWP) and Vaux's Swift are both Candidate Species for listing. The remainder are Priority Species considered for listing: flammulated owl, purple martin, western bluebird, fisher, wood duck, Barrow's Goldeneye, common goldeneye, bufflehead, hooded merganser and marten (102). The primary compilation that the WHMP is built on (329) based snag requirements solely on nesting requirements, which will likely not sustain viable populations of cavity nesters (42, 70, 102, 236).

"Several major lessons have been learned in the period 1979-1999 that have tested critical assumptions of (...) earlier management advisory models" (70). In 20 years of research since the WHMP was written, advances, particularly in radio telemetry and GPS have allowed researchers to better determine habitat preferences, and GIS mapping of habitat types and features, plus an acute awareness that "dead wood (snags and coarse woody debris) is a crucial component of healthy, biologically diverse forests" (69) have led to vast numbers of research projects showing that cavity-nesting bird (CNB) density

is positively correlated with snag density (112), and particularly with the density of large class II & III hard snags (140). Two large scale and very detailed projects in particular have been undertaken to quantify the amount of woody debris that exists in PNW forests as well as amounts required to maintain healthy populations of cavity nesting species. An overview of these two grand-scale compilations is provided below:

4.2.2 *Comprehensive Studies of Dead Wood in Pacific Northwest Forests*

The DecAID (67) advisory tool summarizes habitat associations of wildlife in terms of dead wood diameter and abundance. It can be used to determine the levels of dead wood needed to provide habitat for species of interest and is based on studies of actual species use of dead wood as well as inventories of dead wood in forested stands. DecAID is an Internet-based summary, synthesis, and integration (a “meta-analysis”) of the best available science: published scientific literature, research data, wildlife databases, forest inventory databases, and expert judgment and experience. The information presented on wildlife species’ use of snags and down wood is based entirely on scientific field research and does not rely on modeling wildlife populations. As such, it offers new ways of estimating or evaluating sizes and densities or amounts of dead wood that provide habitat for many species and ecological processes.”

Where estimates from both of these types of data converge (i.e. where field studies report a certain number or size of snags used by a particular species and the inventory plot data also report a similar number or size of snags), additional credence is given to the resulting densities and sizes suggested by the advisory tool. DecAID provides a very comprehensive compilation of species needs of dead wood, whereas the second compilation referenced below (64) reports primarily on inventory plot data collected across the PNW. However, the researchers suggest that appropriate management areas are on the order of 20 square miles, i.e. entire watersheds, not typically small tracts of land like the Lake Chaplain or Spada Lake areas.

The District evaluated DecAID’s recommendations for the Westside lowland conifer-hardwood forest type – larger tree and small/medium trees structural conditions, which seemed most applicable to forest types in the Lake Chaplain Tract. Suggested densities and sizes in DecAID are based on Tolerance Levels (TL) - an 80% tolerance level means that 80% of the population has a value for the given parameter that is between 0 and the value for the 80% TL. These are calculated based on 90% certainty levels. Example: an 80% TL of wildlife use of snag diameter means that 80% of all individuals observed use snags less than or equal to some specified dbh, and 20% use snags greater than that dbh. The tolerance levels describe dead wood conditions across the total area within the vegetation condition.

Regional Patterns of Dead Wood in Forested Habitats of Oregon and Washington (64) is an analysis of dead wood across 49 million acres of federal and non federal lands in OR & WA. This is "the most comprehensive study yet available of dead wood across both

managed and unharvested forests of all ownerships in the PNW." The compilation includes data from more than 16,000 field plots across 9 habitat types.

The researchers have cautioned that applying the values stated in their findings across entire landscapes is not feasible and would not mimic natural conditions, since some of the plots found no snags, and a small proportion of the plots contained very high densities of snags (70). Data from unharvested natural stands should be used as a baseline to determine densities and distributions of dead wood to be provided (67). Since they are fluid through time, changing with disturbance patterns and regeneration of the forest, the complete range of dead wood values shown in the database results should be provided across the landscape or watershed to provide for all species on the curve (67, 296).

4.2.3 *Densities, Sizes and Characteristics of Snags Required by Primary and Secondary Cavity Nesters*

Primary cavity excavators (PCE) are vital components of forest ecosystems, because they are the only inhabitants capable of creating cavities in dead or decaying wood, which are in turn used by approximately 100 additional species. Some PCE's excavate multiple cavities each year, thereby providing habitat for numerous other species. The Pileated Woodpecker (PWP) for instance, excavates a new nest cavity each year (40, 290), creates an average of 7 different roost trees in a 3 to 10 month period, and may use up to 11 roosts during this period (40, 42, 293, 309). This large forest dwelling bird is the most capable cavity excavator in PNW forests, and is responsible for creating much of the nesting and denning habitat used by secondary cavity nesting species (SCN). Created cavities or natural hollows within trees that are exposed by the PWP are used by SCN species ranging from squirrels and marten to swifts and bears. Due to habitat fragmentation and loss of old-growth, the PWP has declined dramatically from historic levels and is now a candidate for endangered species listing (102). Because of its role as a key habitat modifier and due to its potential listing as endangered, many studies have been conducted regarding habitat requirements of the PWP. Much of the following data stems from these studies, but also included are studies of the other PCE's and SCN's known to inhabit the region.

Foraging:

Studies of snags used for foraging show selectivity that often varies by species, with some species tending to utilize down logs as foraging substrates, while others foraged more often on live trees or shrubs. Among those that selected live trees, deciduous trees were more often selected because they tended to harbor larger quantities of arthropods (175). Researchers have recently realized that foraging habitat is as important as nesting habitat, if the needs of these species are to be met. Previously, any substrate over 8" dbh had been thought to be available for foraging year round (225). However, the consensus now is that under a forest canopy, logs on the ground may remain too moist even during the drier summer months to harbor significant quantities of carpenter ants, the primary food source of PWP (158).

In nearly all cases, the largest sizes (tallest/longest and largest diameter) of dead wood available were selected as foraging sites (158, 175, 225, 293). Woodpeckers also often

selected sites that had higher densities of these habitat attributes and large live conifers than the surrounding area (**140, 158**). Areas with an abundance of small snags and trees (common to young forests) were often avoided by cavity nesters (**140**).

Nesting:

Characteristics of trees used for nesting varied somewhat from those of trees used for foraging (**40**). Whereas foraging is found primarily on snags, live decadent trees (broken tops or other significant defect) of the largest sizes (tallest and largest diameter) were also selected for nesting (**140**); in some cases making up half of the nest sites found (**19, 40, 42**). Live decadents are typically created by damage to the top of the tree allowing rot to enter but not killing the tree, or heart rot entering a live tree through a small injury. Cedar is the most commonly occurring decadent tree found in our area, and as such is preferred for roosting (**42**). Silver fir is often selected for nesting because it has a greater tendency to acquire heart rot. Hemlocks are not often selected for either nesting or roosting due to the higher rate of decay from the outside-in, but when they are selected, a majority of the time they are decadent, but not dead (**42**). Due to their low density and slow rate of creation, these decadent trees are now considered to be more important for nesting by PWP than snags (**40, 42**). Those live trees that were used were typically very large in diameter and very tall as well (**140, 158**). In fact, woodpeckers have been shown to select the largest and tallest snags available in any given forest type (**236**) with height and diameter being the most important determinants in which snags are used for nesting (**140**). Snags 23-33 yards tall were used 2.5 times greater than their availability; 34-44 yards tall were used 5.5 times availability, and snags taller than 44 yards were used 9 times their availability (**140**).

When snags are chosen for nest sites, those in the intermediate stages of decay (classes II & III) are often favored, and selection for nest trees increases as diameter increases (**140**). Height of snags was also very important in the selection of nest sites. Taller trees were favored (**173, 293**), and mean nest cavity heights were 73 feet (**293**). Retaining or creating larger diameter snags and decadent trees will not only meet the needs of a larger variety of species, but in the end may be more cost effective because they last significantly longer than smaller snags (**101, 112, 236, 245**).

Due to the favorable growing conditions and low incidence of stand replacement fires, trees tend to be larger in this region than many other areas. Numerous studies of nesting habitat, (**19, 42, 168, 293**) have reported that the largest mean nest tree sizes (40+” dbh and 130’ tall) and highest nests (116’) occur in the NW Cascades region.

Nesting and roosting sites had significantly higher densities of snags and defectives and a greater diversity of tree species than areas not selected for nesting or roosting sites (**42, 293**). The probability that a site would be chosen for nesting or roosting increased 300% for each additional decadent tree/acre, 200% for each additional tree species/acre, and 130% for each additional large (≥ 20 ” dbh) snag/acre (**42**). Dense midstory and understory cover was also a determining factor in nest areas selection (**140**).

Roosting:

Roosting habitat is required for security from predation and adverse weather conditions. These roosts may be cavities created in prior years, or may be newly excavated; as noted above, the PWP creates an average of 7 different roost trees in a 3 to 10 month period and may use up to 11 roosts during this duration (40, 42, 293).

Conditions found in roosting habitat differed from nesting habitat for many CNB's. Nest trees typically had only early stages of heartwood rot, but roost trees usually had advanced stages of heartwood rot (40). This advanced heartrot has often formed large natural cavities inside the decaying tree. Species such as bats and Vaux's Swifts are known to be dependent on these large chambers (290), often with entries created by PWP's for roosting and nesting (123). The lack of these structures is believed to be a limiting factor for Swift's, which as mentioned above, are a candidate species for listing as endangered (123). One study on Vancouver Island found that 67% of bats roosts were in snags (290), and that they used the tallest trees and snags available, particularly those that protruded above the canopy (67).

Older cedar trees are prone to developing heartrot while the living sapwood of this species is highly resistant to decay, which results in ideal conditions for creation of large hollow internal chambers utilized by many wildlife species for nesting and roosting (67, 122, 123).

The location of foraging, roosting and nesting substrate is very important, as many species of CNB's will not venture into openings, due to a much higher risk of predation (122, 158). Shelterwood cuts, where a small number of the dominant trees are retained during harvest, are an option for providing safe habitat in an area where timber production is also an objective (122). Retaining or creating snags in riparian and wetland zones is particularly important, since several species preferentially breed close to streams and wetlands (wood duck, Barrow's Goldeneye, common goldeneye, bufflehead, hooded merganser, osprey, PWP, 102, 140). These areas are also valuable as foraging habitat, typically representing areas of higher hardwood tree densities (122, 140) which have also been shown to be selected in greater proportion than available by CNB (233).

The DecAID (67) notes state that managing entire landscapes at the highest Tolerance Level is impractical both biologically and economically, thus they suggest managing portions of the landscape at the 80% TL and others at lower densities, such as those suggested by the 50% TL.

4.2.4 Distribution of Snags

Appropriate distribution of snags across the landscape is important because woodpeckers are territorial and will not use a tree occupied by another woodpecker (140) so a reduced density of snags or snags too closely aggregated can lead to competition for nest sites, and may reduce the number of cavities available to secondary cavity nesters (293). Due to the nature of tree-killing events (fire, disease, insects, etc.) snags often occur in moderately dense patches, unevenly distributed across the landscape (140, 293). A

combination of evenly distributed and clumped snag patterns would best mimic natural conditions (100, 102). At the stand level, a mix of clumped and more widely distributed snags should occur (67, 70). Clumping of snags also enhances nesting habitat for species such as the PWP and other cavity nesting species by reducing energy expenditures in the search for food (100).

Habitat edges, which are often higher in diversity of plant and animal species, were chosen more often than random sites for CNB nests (236). Creating or retaining snags in these areas may also reduce the amount of potentially hazardous work areas.

4.2.5 Forest Management and Cavity Nesting Species

Forest management is the largest single factor in the decline of CNB's, due to the loss of habitat features such as large old trees and snags, as well as the problems associated with forest fragmentation, but there are techniques that can allow for timber production as well as maintaining suitable habitat. Uneven-aged forest management can help to provide large trees and appropriate canopy closure to maintain suitable nesting and roosting structure for CNB's (122). By creating multiple canopy layers and a dense understory of shrubs, habitat diversity is increased, which leads to higher rates of use by CNB's (140). An uneven vertical profile, often created by canopy gaps, helps to establish and retain this increased diversity (140, 236). Large dominant trees preserved from prior timber rotations, the number of canopy layers and the density of large hard snags are all positively associated with CNB abundance (290). Even though mature and old-growth habitat are considered high quality habitat, forests as young as 40 years old are used by some CNB species if large residual snags are present (20, 122, 139, 236). Pileateds utilize younger forests primarily for foraging, and in one large study that used radio-telemetry to track PWP home range and habitat preferences, nearly half of their home range was comprised of 70 year old forests, although old growth was still a preferred habitat (92).

Longer timber harvest rotations would allow trees to grow larger, as well as decreasing the number of snags which have to be removed for safety reasons, thereby retaining more of the larger snags that are most preferred (140).

Tree characteristics that are often considered to be defects may be of great value to wildlife. Mistletoe brooms provide important nest structures for several owl and squirrel species as well as marten and murrelets (67, 70, 230, 290).

Timber management occurring during the main nesting season of cavity nesting birds and mammals (typically May-July) will unintentionally destroy nests and nestlings (288, 309).

4.3 Coarse Woody Debris

Many Pacific Northwest wildlife species show a strong association with dead wood, including coarse woody debris, which provides cover for breeding and dispersal for amphibians, reptiles, and terrestrial mammals, and cover and foraging opportunities for birds. (244, 325). Since the publication of management guidelines for western Oregon and Washington by Brown et al. in 1985 (48), (some of which appear as prescriptions in the WHMP), new research has indicated that more snags and large down wood are needed to provide for the needs of fish, wildlife, and other ecosystem functions than was previously recommended by forest management guidelines in Washington and Oregon (70).

The District's review of new research included field studies, management guidelines and an important management advisory tool, the DecAID Advisor (67). Most field studies report percent cover and/or volumes of CWD associated with various forest seral stages or different silvicultural practices, using a variety of definitions of what constitutes CWD. Field studies and guidelines offered some correlations between quantities, sizes and decay stages and the quality of wildlife habitat, but recommendations on CWD for the benefit of individual species are not as well established as for snag trees.

4.3.1 Field Studies and Management Guidelines

The mass of CWD in the Cascades followed a U-shaped pattern for stands <500 yr old: moderate levels were present in stands <80 yrs old, lowest levels in stands 80 – 120 yrs old, and the highest levels in stands 400 – 500 yrs. old. Some young stands may inherit CWD and live trees from preceding stands but in mid-rotation CWD declines (178). CWD has a longer lag time in forests than snags and is less likely to be disturbed by management activities (70). A chronological sequence of unmanaged forest stands in the Cascades produced the results shown in table 4.3.1-1 (178).

Table 4.3.1-1. Characteristics of CWD in Washington Cascades forests (from Spies et al 1998 (178)).

	Young stands	Mature stands (80 yrs)	Old Growth
# logs ¹ /ha < 30 cm diameter	456	353	213
# logs/ha 30 – 60 cm	194	133	208
# logs > 60 cm	64	23	66
Cover (sq m/ha)	1136 (9.8%)	715 (6.5%)	1060 (9.3%)
Mean diameter (cm)	33	32	55
Decay class	Primarily 3, 4, 5	Evenly distributed in 2, 3, 4, 5, but higher % in class 2 than in young stands	Primarily 2, 3

¹ All logs >10 cm diameter (large end) included.

Habitat value increases with CWD diameter, and the availability of a diverse array of decay stages of snags and logs. Average diameter of snags used by all wildlife species for nesting or denning exceeds 50 cm. Chipmunks selected logs that have larger average diameters than randomly available wood to use as travel paths. Den sites for large animals (e.g. bear) are limited to logs of >80 cm. Current agency guidelines for augmenting volumes of woody debris in managed forests may be inadequate to maintain populations of all associated species **(70, 244)**.

The management strategy for species associated with dead wood should ensure spatial and temporal continuity of habitat **(324)**. Managers should retain existing large snags and logs during timber harvest, and plan for future recruitment of dead wood. Retained trees can be clumped in patches for safety and operational ease. Managers have a variety of advisory tools, including DecAID **(67)** and the Coarse Wood Dynamics model **(37)** to plan dead wood management **(244)**.

A field study in western Oregon **(178)** reported CWD volumes ranging from 14 to 859 cu m/ha, and captured few salamanders in stands with less than 100 cu m/ha. In contrast, Oregon forest practices require 1.5 cu m/ha CWD and Federal guidelines (1994 USFS and BLM standards for habitat management for late-successional and old growth forest related species within the range of the northern spotted owl) require 37 cu m/ha. "Our study suggests that current management guidelines for CWD retention may not provide adequate habitat for forest-floor vertebrates that depend on this component of the habitat." The authors suggest that retention of CWD in managed stands should model CWD found in natural stands: In the western Cascades, the average is 248 cu m/ha in natural young stands <80 yrs old, and 148 cu m/ha in 80-120 yr old stands **(178)**. Authors of another field study in western Oregon suggest that CWD retention in the range of 100-300 cu m/ha is more likely to provide adequate CWD for terrestrial salamanders **(197)**.

A field study of small terrestrial vertebrates in southwestern Oregon that was part of the DEMO study **(214)** compared dead wood loads between capture and non-capture sites. CWD volume ranged from 50 to 860 cu m/ha on pre-harvest mature forest stands. Species richness of all terrestrial vertebrates pooled increased with increasing CWD volume. Species richness of small mammals, insectivores and amphibians all correlated positively with CWD volume. CWD volumes in this study were greater than 5x the current CWD Federal targets for SW Oregon (1994 USFS and BLM standards). If stands are managed to Federal targets, "the full component of small terrestrial vertebrates typical of PNW forests will not be realized" **(208)**.

Pileated woodpeckers rarely forage on logs in the closed-canopy forests of coastal Washington, concentrating instead on snags (95%). Microhabitat conditions in logs in coastal forests may be too cold and wet to support carpenter ant colonies, which occupy logs in drier habitats. In contrast, pileated woodpeckers forage on logs and stumps in northeastern Oregon **(158)**. No information was found on foraging preferences in the Washington Cascades.

Aubry and Raley (**43**) reviewed Forest Service guidelines for retention of logs during timber harvest on matrix lands in the Northwest Forest Plan:

- In western Washington leave 240 linear feet of logs/ac ≥ 20 in diameter. Logs < 20 ft in length cannot be credited toward this total.
- Decay class 1 and 2 logs can be counted towards these totals. Down logs should reflect the species mix of the original stand.

Another recommendation based on 16,000 field plots distributed over 9 wildlife habitats found that average density of down wood >5 inches in diameter ranged from 47 to 670 pieces per acre (**64, 69**).

Guidelines for maintaining marten in BC managed forests state that CWD is the single most important attribute selected by marten, and that the largest diameter CWD available on a stand should be retained. Both sound and decayed CWD should be saved, and piling logging debris is a desirable supplement (**134**). Other guidelines from BC state that aggregated logging residuals (logs, slash piles and windrows) are used by several small mammals, both predator and prey. More evenly dispersed retention favors some fungi and bryophytes. “Because there is no unequivocal best way to distribute logging residuals, the wisest approach is not to do the same thing everywhere” (**210**).

Distribution can be manipulated by retaining live trees to fall after harvest.

Recommendations: Logs as small as 6 cm are used by shrews, but in some forest types, larger mammals prefer significant amounts (100 – 200 cu m/ha or more) and sizes (>50 cm diameter) of downed wood. Mammals such as marten, fisher and black bear require scattered, large pieces, 50 to 100 cm diameter (**210**).

A study of marten in northern California (**162**) made the following observations:

“Preserving large snags and logs for marten and leaving cull logs after timber harvest should benefit marten.” Average densities in known marten habitat were 46 snags, 66 stumps, and 39 logs per hectare. “The diameter of snags, stumps, and logs left for marten should be 80 cm or greater. Snags should be at least 4m tall, stump heights at least 80 cm and log lengths at least 10 m.”

In terms of percent cover of the forest floor, Carey and Curtis (**27**) recommended using variable density thinning with multiple entries into harvested units to meet a target of 15% cover. The CWD size range should be 10 – 100 cm in diameter.

Experiments on decay rates of logs (45 – 65 cm in diameter and 5.5 m long) have produced some early results (**131**):

- Western hemlock logs decomposed slower than expected.
- Western hemlock decomposed slower than Douglas-fir for the first 3 years, but in the long terms the opposite is expected to occur.
- Decomposition of Pacific silver fir was more rapid than expected (9% of the mass lost between the third and fourth years).

- Douglas-fir and western red cedar are decomposing at rates close to those observed in chronosequences.
- A large variety of insects and decomposers cause the start of decay process.
- Excess moisture limits respiration of decomposers.
- Fungal fruiting bodies are the major pathway through which nitrogen is exported from logs during early decomposition of Western hemlock.

4.3.2 DecAID Advisory Tool

DecAID (67) is a planning tool that helps managers evaluate the effects of forest conditions and management activities on species that use dead wood. DecAID attempts to synthesize habitat association data from wildlife studies for individual species, or groups of species, and predict what population levels might be supported by different quantities and sizes of dead wood. It can be used to determine either the species that would be provided for by retaining various densities and diameters of dead wood, or the levels of dead wood needed to provide habitat for species of interest. The DecAID review and synthesis is up-to-date and comprehensive, and the District reviewers felt it was not necessary to replicate their work. There are limitations to its application, however. DecAID helps managers determine CWD sizes and levels needed to meet wildlife management objectives on a broad scale, such as watersheds, physiographic provinces and large administrative units like Forest Service ranger districts. Its authors state that it is not intended to predict species composition in a given geographic area like a forest stand.

The District evaluated DecAID's recommendations for the Westside lowland conifer-hardwood forest type – larger tree and small/medium trees structural conditions, which seemed most applicable to forest types in the WHMP management lands. Wildlife use data and inventory data from unharvested plots both support managing snags at the 80% tolerance level (Tolerance Level (TL) - an 80% tolerance level means that 80% of the population has a value for the given parameter that is between 0 and the value for the 80% TL. These are calculated based on 90% certainty levels. Example: an 80% TL of wildlife use of snag diameter means that 80% of all individuals observed use snags less than or equal to some specified dbh, and 20% use snags greater than that dbh. The tolerance levels describe dead wood conditions across the total area within the vegetation condition.)

Many of the general management recommendations for CWD repeat those for snags, including:

- If the objective is to manage for natural conditions rather than focusing on wildlife species, mimic the distribution of unharvested acres (unharvested proportion of the landscape) in different snag density classes across the landscape. The percentages should be thought of as guidelines, since distributions largely reflect plot size and sample design. Balancing high, moderate and low densities of dead wood across a landscape may be desirable.

- To provide longer lasting dead wood, consider that time from death of tree to fall down varies by cause of death. Trees killed by mammals, insects and suppression are most likely to remain standing as snags, while trees killed by windthrow and root disease are most likely to fall down soon after death. Western red cedar logs will decay more slowly than Douglas-fir or hemlock.
- Provide undisturbed, high-density clumps of down wood of 5 to 19% cover (includes all decay classes). The 80% TL for unharvested inventory plots is 12% cover, but many species are associated with % cover of CWD above the 80% TL. Manage for a mix of sizes of CWD, averaging 30 to 50 cm (12 to 20 in) in diameter for the stands. Minimum size for the inventory is 10 cm (4 in). Manage some pieces of CWD at least 60 to 80 cm (24 to 32 in) in diameter, see Table 4.3.2-1
- Length of individual CWD pieces was reported in DecAID in terms of species that used logs in certain length categories, and the data on this attribute were sparse. Mean down wood lengths ranged from 6 m (20 ft) for roosting long-eared myotis to 20 m (66 ft) where Oregon slender salamander were present. All species except Van Dyke's salamander were represented by only one study. All but 2 studies looked at either salamander presence or nest use of down wood pieces. The other studies looked at foraging use of down wood by pileated woodpeckers, which is uncommon in the Jackson Project area, and roost use by long-eared myotis. Doyle (1990) found that the number of Townsend's chipmunk captures was significantly correlated with the total length of decayed logs. Hartwig (1999) found that pileated woodpecker foraged on logs that were larger in diameter and length. Corkran et al (1997) found that an increase in log length increased the odds of Oregon slender salamander occupancy on a site.
- Data are not available on the spatial distribution of dead wood within stands. Species often use clumps of snags & dead wood. Numbers and sizes of clumps are not indicated by this data. Areas between clumps should not be devoid of snags; a mix of clumps and more widely distributed snags should occur at the stand level.
- Retain all hollow trees, snags, and logs. Cedar and hemlock are more susceptible to hollowing.
- Avoid disturbance of class 5 CWD as it is important for some species of wildlife and for site productivity. Manage for stand average percent cover of about 12% of class 1-4 CWD.
- Removing woody structure can have short-term benefits to planted seedling growth but longer-term adverse effects on overall forest productivity.

Table 4.3.2-1. Distribution of CWD sizes on unharvested forest inventory plots in the Westside lowland conifer-hardwood forest type - larger tree structural class.

Down wood diameter (cm)	% down wood (>12.5 cm) in size class	% of area with down wood in size
<12.5'	N/A	4
12.5 - 24.9	11	76

Down wood diameter (cm)	% down wood (>12.5 cm) in size class	% of area with down wood in size
25 - 49.9	40	83
50 - 99.9	42	71
>100	7	15

¹ Down wood less than 12.5 cm diameter was not measured in the forest inventory plots; therefore, the value in the first row reflects % of plot-sized areas with no down wood, and/or % of plot-sized areas where all down wood is <12.5 cm diameter.

4.4 Nest Structures

There has not been a substantial amount of new information regarding nest structures published in the last 17 years that are geographically relevant to the PNW, however, some studies from Midwestern states can provide guidance for certain issues, such as nest box checking strategies and predation reduction tactics. Among the findings:

- Individual cavity-nesting ducks that are successful are more likely to return to the same nest site than those that are unsuccessful **(144)**.
- Those females that used the same box in subsequent years also began nesting earlier (13 days) and had larger clutches than those that returned to the same wetland, but chose a different box than the prior year **(144)**.
- During nest box checks, membranes counted within 5 days post-hatch provided an accurate estimate of number of ducklings; add 1 to this count to derive the most accurate count of hatchlings **(147)**.
- To maximize nest box use and duckling production, nesting materials should be removed after peak of nesting season and again immediately after the breeding season. This will also allow better estimates of nest box use, success and productivity **(146)**.
- Clutches in traditional boxes (visible duplex boxes) were less likely to hatch than those in non-traditional boxes (hidden/dispersed) (45% vs. 64%), resulting from brood parasitism (multiple females depositing eggs in the same box, intending for the original box occupant to raise their young) **(145)**.
- Ultimately, the same number of fledglings were produced from each box (9.0 in traditional vs. 9.2 in non-traditional), but a much greater number of unfledged ducklings resulted from the traditionally placed boxes (10.9 vs. 4.4, respectively) **(145)**.
- Nest box placement and frequency of brood parasitism were directly related **(145)**.
- Parasitism rates inferred from clutch size alone are unreliable **(148)**.
- Parasitism is inferred from the following 4 criteria: **(148)**
 - addition of ≥ 2 eggs in a 24 hour period;
 - addition of eggs after incubation has begun;
 - eggs that differ in color or shape from the remainder of the clutch;

- "supernormal" clutch size.
- Boxes hidden from view result in lower nest parasitism and a higher hatch rate **(145)**.
- Rates of nest box parasitism were found to be directly related to the location of the box, and not related to scarcity of available boxes **(145)**.

4.5 Right of Way Management

Minimal new information is available on ROW management, but timing appears to be a significant factor in determining the success of management activities. Mowing or cutting of seedlings on ROW's is most conducive to killing the trees when done in the late summer or early fall. The seedlings (particularly deciduous trees) will have pulled stored starches from their roots for leaf growth, but will have returned only a small amount back to the root stores. When trees head into dormancy in the fall, energy is transferred back to the roots, so cutting off the above ground portion of the plant at this time only stunts the growth, but is much less likely to kill it. Cutting in late summer reduces the amount of starch stored in the roots for revival and also creates great stress on the plant due to moisture loss through the cut top which is now exposed to the summer heat.

4.6 Deer Forage Management

The District's search of databases on deer forage turned up information on their preferred habitats **(59, 60, 326, 327)** and the effects of opening gaps in the forest canopy on some of their preferred shrubby food plants, such as huckleberry **(109, 282)**. Information obtained in the database search remains consistent with the management guidelines that influenced the development of the WHMP (for example, **58, 259**).

In general, a patchy forest with small openings usually provides better forage than a dense forest with a closed canopy. Deer use cover to limit energy output and hide from predators. Having all necessary resources close together reduces the time spent and the distance traveled to obtain them. Suitable summer habitat includes the coolest aspects and elevations with moist areas that offer abundant herbs. Winter habitat includes elevations <900 m, slopes 30 – 80%, southern aspect, tall, large-crowned conifers (or 65-75% crown closure), cedar-hemlock thickets, tall shrub understory, and arboreal lichens (typical of later successional forests) **(59)**. Maintaining areas permanently in an early successional vegetative stage, with plantings of preferred forage species and fertilization will benefit deer **(259)**.

Results of long-term radio telemetry studies in the late 1980s through 1990s on deer movement patterns appeared after the WHMP was written. The Integrated Wildlife-Intensive Forestry Research Program of the BC Ministry of Forests tracked the movements of 89 radio-collared black-tailed deer for 9 years on coastal Vancouver Island sites. Habitats included low-elevation (200 – 300 m asl) river valleys with young (6 - 45

year old) forests, deforested mid-slopes, and old growth forests in higher elevations (>600 m) (59). Significant findings of this study include:

- Three movement patterns were distinguished: (1) Low-elevation (200 – 300 m asl) residents who always stayed close to natal ranges, (2) regular migrants who always moved from higher elevation summer range to lower elevation winter range, and (3) irregular migrants, who had mid-elevation natal ranges and only used lower winter ranges when snow pack forced them to move.
- Resident deer stayed in the low-elevation ranges and habitats all year. Low-elevation resident deer had small ranges (1.9 km²) that normally included adequate forage in young and open forest.
- Radio-collared deer were rarely found more than 250 m from forested cover. Resident deer spent 65-75% of the time in young forests and up to 15% of the time in open areas. Migratory deer showed consistent changes in their seasonal habitat choices during severe winters, preferring south-facing old forests at 400 – 600 m elevation. Logging has reduced these older forests significantly, and the author predicts that fewer deer will establish home ranges at higher elevations, and those migrant populations will be less able to withstand severe winters.
- Young deer rarely dispersed to new ranges, expand their natal ranges or colonize other areas. Radio-collared deer were rarely found more than 1 km from their last location. Deer habitually used the same sites, and their preferred habitats were often not ideal following logging. Strong site fidelity may limit the ability of deer to respond to rapid habitat changes, or alternatively may limit their ability to find sites outside their normal range that have been improved by management.
- Management of young forests to improve winter habitat suitability for deer may only benefit deer in the immediate vicinity, at least initially. There may be a lag time before the population responds.
- Harvest and road construction, combined with fragmentation of suitable winter habitat, may intensify predation especially on migratory deer. The authors recommend that blocks of older intact forests be set aside at lower elevations because they are essential to rebuild deer populations (59).

4.7 Riparian Habitat, Streams and Wetlands

4.7.1 Definitions

All jurisdictions that are involved (or potentially involved) in regulation of wetlands, streams and riparian habitat on the Jackson Project use the same definition of wetland: “Those areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs, and similar areas.” [(Corps of Engineers and Environmental Protection Agency 33CFR 328.3(b) and Federal Register 1980 and 1982), (Washington Department of Ecology, RCW 36.70A Growth Management Act and RCW

90.58 Shoreline Management Act), (Washington Department of Natural Resources WAC 222-16-010), and Snohomish County SCC 30.62.015(30)] Wetlands must present distinctive characteristics of vegetation, soils and hydrology in order to be subject to these regulations.

Wetland identification (for jurisdictional purposes) and delineation do not equal wetland classification. The most widely used wetland classification system is the Cowardin System (**331**). Where Snohomish County has jurisdiction SCC 30.62.A.230(2), wetlands are additionally classified and rated by a functional rating system, (Washington State Wetland Rating System for Western Washington (**332**), but this system is not prescribed at present by other regulatory agencies such as DNR or the Federal agencies. The DNR Forest Practices definition and delineation methods for wetlands are similar to the definition and delineation used by Federal, State and local jurisdictions, but wetlands are classified into unique types (WAC 222-16-035):

- Type A wetland – Nonforested wetlands which are greater than 0.5 ac, including any acreage of open water, and are associated with at least 0.5 ac of ponded or standing open water. All forested and nonforested bogs greater than 0.25 ac.
- Type B wetland – All other nonforested wetlands greater than 0.25 ac.
- Forested wetland – Wetland that has, or if trees were mature would have, a crown closure of 30 percent or more

This difference is important because it determines how buffer zones are designated for Forest Practices wetlands (see Section 4.7.2).

Streams are defined by Snohomish County (SCC 30.62.010(26) as “those areas where naturally occurring surface waters flow sufficiently to produce a defined channel or bed which demonstrates clear evidence of the passage of water including, but not limited to, bedrock channels, gravel beds, sand and silt beds and defined-channel swales. The channel or bed need not contain water during the entire year.” A lake is defined by the County (SCC 30.62.010(15) as “a naturally existing or artificially created body of standing water that: (1) is present on a year-round basis; (b) occurs in a depression of land or expanded part of a stream, including reservoirs; (c) is greater than 6.6 feet (2 meters) in depth at the deepest point; and (d) has less than 30% coverage by trees, shrubs, or persistent emergent vegetation.” The DNR (WAC 222-16-030) employs a water typing system that does not define streams or lakes but classifies them so extensively that a general definition is not needed. The County recently (Oct. 1, 2007) incorporated DNR’s water typing system into its regulations for streams, lakes and wetlands in fish and wildlife habitat conservation areas (SCC 30.62A.230(1).

Riparian zones have various definitions; in the statutes the definitions appear to have limited scope. For example, Snohomish County (SCC 30.62.010(22) refers to “riparian wetlands”, i.e. “those wetlands that are fully or partially contained within 100 feet of Type 1, 2 or 3 streams, within 25 feet of Type 4 streams, or within 10 feet of Type 5 streams”, but does not consider non-wetland riparian habitats. DNR’s definitions (WAC 222-16-010) reference riparian function and riparian management zones but do not

provide a general definition. The District's review included a number of technical reports, review articles and guidelines that describe and define riparian habitats more extensively, some of which were written with the intention of providing the scientific baseline or justification for Snohomish County's revised critical areas ordinance (**35, 87, 88**). Review articles cite the confusion of terms and definitions for riparian habitat based on hydrologic, topographic, edaphic, and vegetative criteria. One unifying feature is their association with streams or rivers (lotic systems). Riparian zones can be defined as zones of direct physical and biotic interactions between terrestrial and aquatic ecosystems; boundaries of the riparian zone extend outward to the limits of flooding and upward into the canopy of streamside vegetation (**287**).

WDFW (**74**) utilizes a structural and functional definition that describes the needs of fish and wildlife. A riparian habitat area (RHA) is defined as the area adjacent to aquatic systems with flowing water (e.g., rivers, perennial or intermittent streams, seeps springs) that contains elements of both aquatic and terrestrial ecosystems which mutually influence each other. The RHA encompasses the full range of habitat functions necessary to support riparian-associated fish and wildlife. RHAs differ somewhat from riparian "buffers". The concept of riparian buffers is usually applied to the buffering of streams from the effects of adjacent, more upland activities. As such, buffers typically only address the retention of functions needed by fish and stream-dwelling wildlife, e.g. some amphibians. They often fail to adequately accommodate the needs of other wildlife species, especially those upland species that use riparian areas to varying degrees. RHAs also encompass the functional aspects of riparian areas relative to uplands. Therefore, RHAs present the opportunity to manage riparian habitat as a more completely functioning system in which streams and uplands mutually influence one another.

RHAs should be sufficiently wide to achieve the full gamut of riparian and aquatic ecosystem functions, which include but are not limited to: 1) protection of instream fish habitat through control of temperature and sedimentation in streams; 2) preservation of fish and wildlife habitat; and 3) connection of riparian wildlife habitat to other habitats. Width is one of the most important variables affecting riparian corridor functions (**74**).

4.7.2 Buffer Zones

Most of the guidelines and reviews included comprehensive discussions of the protection of riparian zones and wetlands and their functions and dependent wildlife species through buffer zones. Some offer advice on application of fixed-width vs variable-width buffer zones, and how to resolve these issues using best available scientific analyses. We did not find consensus among the various literature sources in buffer zone widths.

Where forest stand management is proposed, i.e. where Washington State Forest Practices Act (FPA, RCW 76.09 and WAC 222) permits are required, definitions and requirements of the FPA rules must be applied, at a minimum. These requirements were developed following an extensive review of the existing scientific literature, as were WDFW's and Snohomish County's guidelines. The FPA Manual provides buffer zone

widths for water types not yet in effect, but provides a conversion table for the interim water types currently in use. For western Washington, the total width of the riparian management zone (RMZ) for Type S (= Type 1) or F (= Type 2 and 3) waters depends on the Site Class of the area in question:

- Site Class I – 200 ft
- Site Class II – 170 ft
- Site Class III – 140 ft
- Site Class IV – 110 ft
- Site Class V – 90 ft

For type Np (= Type 4) waters, the buffer zone is 50 ft, but the amount of the stream that is actually protected is determined by its length. The FPA further defines RMZ core zones, inner zones, and outer zones for Type S and F waters, for the purpose of defining allowable harvest practices in RMZs. Protection for Type Np and Ns waters includes limiting equipment use within 30 ft of the outer edge of the bankfull width, and mitigation measures designed to prevent sedimentation, such as grass seeding, mulching, or water bars.

The Wetland Management Zone (WMZ) are defined as “a specified area adjacent to Type A and B Wetlands where specific measures are taken to protect the wetland functions.” WMZs may have variable widths based on size of the wetland and wetland type:

Table 4.7.2-1. Wetland Management Zones (WAC 222-30-020(7)).

Wetland Type	Acres of nonforested wetland	Maximum WMZ width	Average WMZ width	Minimum WMZ width
A (including bogs)	>5	200 feet	100 feet	50 feet
A (including bogs)	0.5 to 5	100 feet	50 feet	25 feet
A (bogs only)	0.25 to 0.5	100 feet	50 feet	25 feet
B	>5	100 feet	50 feet	25 feet
B	0.5 to 5			25 feet
B	0.25 to 0.5	No MWZ required	No WMZ required	

Snohomish County developed a very comprehensive review of river processes and aquatic and riparian communities (35). Discussion of buffer widths uses the concept of Site Potential Tree Height (SPTH), the average maximum height to which a dominant old growth tree will grow if left undisturbed (definition from FEMAT 1993). Generalized curves were developed to rate buffer effectiveness for ecological functions, including shade, litter fall, soil moisture, erosion/sediment control, bank stabilization, pollutant removal, large woody debris recruitment, microclimate and habitat. Based on these curves, all but habitat and microclimate functions would likely be protected with a buffer width equivalent to one SPTH. Microclimate functions would need approximately three SPTH for full protection, and habitat functions could require more. Table 4.7.2-2 is a compilation of buffer zone recommendations from the County study. This review has an extensive discussion of fixed vs variable buffer widths, and a review of buffer zone

recommendations, and it compiles literature regarding wildlife habitat benefits provided by buffers of different widths. This review was the basis for the County's recently-adopted revised Critical Areas Ordinance (SCC 30.62), (Table 2.7.2-3). The ordinance states that as habitat functions and values supported by a critical area increase, so do the buffers required to support the functions.

The County's new rules for wetlands first classifies wetlands on the basis of size and structure, and then assigns as buffer width that depends on the functional rating of the wetland. Functional rating criteria include hydrology (floodwater abatement/storage), water quality (pollutant and sediment removal) and fish and wildlife habitat.

Table 4.7.2-2. Buffer Width Recommendations (from Best Available Science for Critical Areas, Snohomish County).

Buffer Width Recommendations from the BAS by Source					
Functions and Values of Riparian Areas	As Reported in Snohomish County BAS Summary (pg. 82)			Kindig report (PC exhibit #66B)	DOE – wetland science, Volume 1
	May	Knutsen / Naef	FEMAT		
Large Woody Debris	33-328' 1.0 SPTH – 262'	100-200'	1.0 SPTH* (200')	75-656' (75-180' w/ outliers removed)	
Temperature / Shade	36-141' 98' min.	35-151'	0.75 SPTH (150')	35-147'	
Sediment Control / Bank Stabilization / erosion control	26-600' 98' min (80%)	100-125' (erosion) 26-300' (sediment)	1.0 SPTH (sediment - 200') 0.50 SPTH (bank stabilization – 100')	Slope < 15% 16-163' Slope > 15% 26-295' Slope Unspecified 49-300'	30-200' (80-99% effectiveness) 16-400' (special conditions apply)
Pollutant Removal	13-860' 98' min (80%)	13-600'	1.0 SPTH (200')	13-600' (13-197' w/ outliers removed)	30-279'
Nutrient supply / Organic litter			0.5 SPTH (100')		
Microclimate	148-656' 328' min.	200-525'	up to 3.0 SPTH (up to 600')		131'
Wildlife Use					49 - 3,280' (most wildlife habitat value w/in 328')
Screening from Wildlife Disturbance	33-656' 328' min.	25-984'	98-600'		49-328'

SPTH = Site potential tree height. Maximum SPTH in Snohomish County is approximately 200'. Local 100-year tree growth potential is approximately 150'.

Source: PDS, January, 2007. Data compiled from Snohomish County *Summary of Best Available Science*, March 2006, pg. 82; Kindig report submitted to Master Builder's Association, November, 2005 and to Snohomish County Planning Commission, May, 2006, exhibit #66B; and DOE's summary of wetland science, *Wetlands in Washington State, Volume 1: Synthesis of the Science*, March, 2005.

Table 4.7.2-3. Buffer Widths for Streams, Lakes and Marine Waters (from SCC 30.62A.320 Table 2a; Water Types defined in SCC 30.62A.230 Table 1).

Water Type	Buffer Width
Type S	150 feet
Type F (with salmonids)	150 feet
Type F (without salmonids)	100 feet
Type Nf	50 feet
Type Ns	50 feet

According to WDFW guidelines (74), recommended riparian habitat area (RHA) widths generally include a zone of riparian vegetation plus a transition zone dominated by upland vegetation. Recommended RHA widths in this document only apply to riparian areas associated with streams and rivers (Table 4.7.2-4). The widths should be applied to both sides of a stream or rivers, with measurements beginning at the ordinary high water mark. For streams with channel migration zones, RHA width measurements should begin at the edge of the CMZ. Appendix C of the WDFW guidelines provides information on riparian habitat functions and the widths needed to retain those functions. This guideline discusses variable buffer width but does not offer recommendations on how to calculate them.

Table 4.7.2-4. Standard recommended Riparian Habitat Area (RHA) widths for areas with typed and non-typed streams, as defined in WAC 222-16-030.

Stream Type	Recommended RHA widths (ft) ¹
Type 1 and 2 streams; Shorelines of the State, Shorelines of Statewide Significance	250
Type 3 streams; other perennial or fish bearing streams (5-20 ft wide)	200
Type 3 streams; other perennial or fish bearing streams (5 ft wide)	150
Type 4 and 5 streams; intermittent streams and washes with low mass wasting ² potential	150
Type 4 and 5 streams; intermittent streams and washes with high mass wasting potential ²	225

¹ If the 100 year floodplain exceeds these widths, the RHA should extend to the outer edge of the 100-year floodplain.

² Mass wasting is a general term for a variety of processes by which large masses of rock or earth material are moved downslope by gravity, either slowly or quickly.

The WDFW guidelines add 100 ft to the RHAs outer edge on the windward side of riparian areas with high blowdown potential, and larger RHA widths may be required where priority species occur, as listed in Appendix D of the WDFW guidelines (74).

Comparing the FPA's rules with WDFW recommendations and the County's new rules, the FPA standards for wetland and stream protection under commercial forestry are less stringent in some regards than those required by local governments for non-forest lands. The FPA does not require buffer zones for forested wetlands and has weaker standards for avoidance of impacts during harvest. It provides standards for buffer protection for certain non-forested wetlands and bogs, and fish-bearing streams, but does not protect most intermittent streams to the extent that local jurisdictions would. The assumption in the FPA is that many of the affected functions performed by forested wetlands and non-fish bearing streams recover during the time they regenerate trees old enough for another cycle of timber harvest. In contrast, the aim of the Growth Management Act (GMA), which guides the County's rule-making, is to protect the functions provided by forested wetlands when forest lands are converted to residential, commercial, or other non-forestry uses. In the opinion of the reviewers working on the GMA standards for the Washington Department of Ecology (DOE) (88), it should not be the intent of the local jurisdiction to make the Forest Practices Act consistent with local government's more stringent requirements for forested wetlands.

The DOE guidelines (88) cite the Washington State wetlands rating systems (332), which divides wetlands into four categories based on rarity, sensitivity to disturbance, irreplaceability, and functions. This hierarchical rating establishes larger standard buffer widths for those in higher categories and smaller standard buffers for those in lower ones. Another way to address site-specific factors while using fixed widths is to have different widths based on the type of adjacent land use, thus incorporating the four factors, discussed earlier, that are known to influence the effectiveness of buffers. A buffer regulation could require a larger buffer width for adjacent land uses with intense impacts and a smaller buffer width if the impacts from adjacent land uses are low. This strategy can be combined with a wetland rating system to provide a more scientific and defensible approach. Other critical factors, such as the characteristics of the buffer itself and the functions of the buffer that are desired, can be addressed by establishing criteria and procedures for varying from a standard width. This approach allows for some site-specific tailoring of the standard widths on a case-by-case basis without the need for developing a detailed formula or methodology for determining the widths.

The criteria for allowing a deviation from the standard buffer width include the various buffer characteristics that have been determined in the scientific literature to be most important. These include slope, soil type, vegetative cover, and/or the habitat needs of particular wildlife species. To reduce standard buffer widths, an applicant should have to demonstrate that a smaller buffer will protect the functions and values of the wetland (88). In addition, compensatory mitigation may be required, which is usually measured in net gains in wetland acres. The acreage required for compensatory mitigation is divided by the acreage of impact, resulting in a mitigation ratio. Mitigation ratios are generally greater than 1:1, reflecting the risk of failure of the proposed mitigation practices and the time lag between wetland impact and achieving a fully functioning mitigation site. Mitigation may consist of a variety of activities suited to the site,

including restoration of former or degraded wetlands, creation of wetlands where none previously existed, or enhancement of the functional values of an existing wetland.

Threatened, endangered, and sensitive (T/E/S) species need specific protection, but this protection cannot be accomplished using the protection measures linked with wetland rating systems. If a T/E/S species is found living in or using a wetland, the appropriate state or federal agency should be consulted to determine what is necessary to protect that species. This information can be considered an “overlay” on the wetland rating. A wetland containing T/E/S species should be protected to meet the requirements of the species as well as the measures associated with its rating category. The T/E/S species using the wetland may need larger buffers or other considerations (e.g., no disturbance during the nesting season). For example, a Category II riverine wetland that provides over wintering habitat for endangered Coho may need larger buffers than those recommended for a Category II wetland that would protect fish that are not T/E/S species (88).

4.7.3 *Management of Riparian Areas and Wetlands*

WDFW developed statewide riparian management recommendations for a very wide range of activities in riparian areas, based on the best available science. There is an extensive review of riparian characteristics, ecological functions, use of riparian habitats by fish and wildlife species, impacts of activities in riparian habitats, requirements (by function and by species), for the protection of riparian zones, buffer zone recommendations, and recommendations for management of riparian areas (74).

Riparian influences on stream habitats include:

- Influence on stream flow
- Influences on water temperature and dissolved oxygen
- Control of stream sedimentation
- Control of stream pollution
- Contributions to the food web
- Structural diversity: large woody debris
- Structural diversity: off-channel habitats
- Relationship to uplands: Riparian habitats can moderate the effects of upland events, but they cannot fully moderate water temperatures or filter impurities if the hydrologic flow from the uplands is a result of rain-on-snow events, erosion, or loss of vegetation is excessive or heavily polluted.

Riparian contributions to terrestrial wildlife habitats:

- Connectivity to other habitats
- Vegetation composition - A mosaic of successional stages and plant communities; in forested areas, a mixture of conifer and deciduous species in mixed age classes, well developed herb and shrub layer, multiple canopy layers
- Abundant food sources and available water, moist and moderate microclimate.
- Snags

- Woody debris, including large logs, stumps, root wads and branches in riparian zone and instream.
- Shape - Irregular edge providing diverse interface between riparian and adjacent upland habitat types
- Associated wetlands, oxbows and beaver ponds

Past forest management regulations and guidelines have focused on the riparian habitat functions of stream temperature control and erosion control, and have not adequately addressed the provisioning of large woody debris to support fish production and wildlife dependant on snags and woody debris **(74)**.

Landscape-level management of riparian areas is required because physical and biotic processes in the floodplain do not operate independently of inputs from the surrounding landscape. Simplification or reduction of woody riparian vegetation is especially harmful to birds' breeding requirements **(287)**.

Preservation of riparian habitats -- Often passive restoration (i.e. stop the activity that is degrading the riparian zone) is sufficient for self-restoration. But sometimes management must do more than just eliminate human-induced alteration; also this includes management to maintain natural functions, e.g., weed control, prescribed fire.

Active ecological restoration – The aim is to return riparian zones to fully functional conditions, recognizing that riparian systems are in a constant state of flux. The authors criticize inappropriate artificial instream structures, reintroduction of extirpated species, and creation of permanent surface water wetlands where natural wetlands were seasonal. These actions must be implemented to recognize the potential of the site and recover its natural ecosystem processes **(287)**.

Relationships between forest management and the integrity of aquatic and riparian systems is complex, and it would be difficult to tailor management actions at the site level to produce desired changes in small stream-dwelling vertebrates at the population level. Changes in riparian forest at the landscape level, however, may influence populations. For example, the percentage of a watershed in late-seral forest, the time since the last major disturbance, or road density may be important to aquatic- and riparian-associated vertebrates, but they are insufficient by themselves to explain population changes **(261)**.

Restoration of conifers to hardwood-dominated riparian forests in the Oregon Coast Range is crucial to the creation of stream habitat favorable to anadromous salmonids **(224)**. Riparian forests should contain a mixture of conifer and hardwood species to provide the diverse kinds of vegetative cover, leaf litter, and large wood input to streams that sustain complex aquatic and terrestrial food chains. Conifers provide the large logs necessary for complex stream habitat. These large logs are the key elements in debris jams, which foster the development of pools, the accumulation of gravel, hiding cover, and off-channel habitat for fish during high flows.

Successful restoration of conifers will require an active approach, including marked reduction of competing shrub and overstory trees, at least in patches. The objective of growing larger conifers often conflicts with restrictions on removing riparian overstory. Thinnings or gap creation are done so conservatively that they fail to provide adequate release of existing or underplanted conifers, but since conifer restoration can be applied in patches, such conflicts should be easy to avoid. Otherwise, most of the conifers will not survive the combination of poor growing conditions and animal damage. Active management of both overstory and understory to give conifers plenty of growing space is the only way to promote conifers into a dominant position (224).

Red alder and bigleaf maple may dominate sites for a century after conifers have been removed, either selectively or in clearcuts. Conifers do not necessarily regenerate and succeed hardwoods naturally without additional disturbance. None of the northwestern conifers are adapted to grow through hardwood-dominated stands in time frames of a few decades. Growth studies indicate that with active management, such as thinning or creating gaps, it may take a century to grow conifer trees large enough [60 cm (24-in.) in diameter] to provide keystone material for stream structure.

Large conifer material useful for stream structure comes from headwall areas, as well as from the immediate vicinity of the lower stream reaches. Thus, it is not necessary to grow all future large conifer debris in the immediate streamside. Headwater drainages with first- and second-order streams form a large part of the forest landscape. Storm events can trigger headwall failures and debris flows that transport huge amounts of large woody debris, sediment, gravel, and boulders to lower stream reaches, where these materials provide important elements of complex riparian and aquatic habitat. Headwater forest areas are often nearly pure conifers, and thinning these forests will promote the development of large trees. Second- and third-order streams often flow through narrow, constrained reaches with steep hillsides. Floodplains and terraces are usually narrow. Where hardwoods dominate the forest, suppressed conifer regeneration may be released by overstory thinning or creating gaps. Where conifers are planted, they will benefit from reduction of heavy shrub or herbaceous competition. The steep terrain often provides topographic shading of streams. Higher-order streams form alluvial valleys that provide more complexity, including wide terraces and side channels or pools that are important for fish refuges during high-water periods. Complex microsites create both challenges (shrub competition and animal browsing and clipping) and opportunities (deep soils for planting and tending conifers) to provide a diverse mix of trees to enhance riparian functions. Stream shading can be created by planting on the south side of streams, or retained by placing gaps, thinning stands, or releasing conifers on the north side of the stream (224).

A field study in western Washington tested the hypothesis that seed availability rather than competitive interactions shapes patterns of conifer regeneration in managed riparian forests. Frequency and density of conifer regeneration were significantly greater within 100 m of remnant forest patches than at greater distances. Where seed sources were present, regeneration was positively associated with CWD and negatively associated with fine litter. Regeneration was most abundant in plots with <10% herb or shrub layer.

No relationship was detected between regeneration density and overstory conifer or hardwood cover. Results suggest that in managed forests, conifer regeneration is largely limited by seed availability and only secondarily by competitive interactions or substrate conditions. The authors suggest green tree retention harvest methods as an effective tool for increasing conifer regeneration in riparian zones **(204)**.

5.0 DISCUSSION: APPLICATION OF CURRENT RESEARCH TO WHMP

5.1 Forest Vegetation Management

The WHMP attempts to utilize forest management practice to promote wildlife habitat features on managed stands, and at the time it was written and approved by the FERC in the late 1980's, it utilized advanced concepts and practices available to foresters and wildlife habitat managers.

This review is intended to look at current literature and ongoing research and compare it to WHMP forest vegetation management practices. Some caution is required in making comparisons and selecting alternative treatments for possible application to WHMP lands. Many of the studies cited in Section 4 were conducted in habitat types and structural conditions that are dissimilar to those found in WHMP lands. Differences in moisture regimes, soil types, etc. may affect responses of forest vegetation on WHMP lands to management techniques that have been successfully applied elsewhere. It should also be noted that most of the experimental studies cited in this review are of relatively short duration. There will undoubtedly be consequences from some of the suggested management approaches that will require adaptation. For example, wildlife damage to young conifer plantations following precommercial thinning was not considered in the original WHMP prescriptions or the more recent literature. A review of management activities on State forest lands adjacent to WHMP lands that have not been documented in the scientific literature should offer good information on likely results of some of the alternative management techniques.

It should be recalled that approximately half of forest stand acreage on the Lake Chaplain Tract is reserved for permanent forest cover, with only minimal patch cutting allowed. On the Spada Lake Tract no clearcutting is prescribed; a light variable density thinning has been applied to some second-growth stands, but most second-growth stands cannot be reasonably accessed for commercial harvest because of road access constraints. The Williamson Creek Tract was acquired for the purpose of providing a large block of old growth forest, and has no timber harvest at all. Thus, the habitat needs for late-successional species are served on a significant portion of WHMP lands by preserving all existing old growth forest stands and many mixed forest stands, and thinning dense second growth stands. Management of 60-year rotation stands occurs only at Lost Lake and Lake Chaplain therefore, management of these tracts is the focus of this review.

WHMP forest management in 60-year rotation stands focuses on promoting habitat for black-tailed deer, using clearcutting as a substitute for meadows and other open habitats that are difficult to create and maintain in the Sultan Basin. Management for deer requires a continuous inventory of open habitat. However, the benefits for deer are transitory, and many other wildlife species such as forest-dwelling birds avoid clearcut openings. Results reported in the literature, as well as the District's studies of deer forage availability on Lake Chaplain clearcuts, show a reduction of the most palatable herbs as

the pole-stage canopy begins to close. Precommercial thinning may delay loss of the understory, but the next entry into these young stands would not occur until the stand is 40 to 45 years post-harvest, with the interim period spent in the stem-exclusion stage (called the closed-canopy sapling/pole stage in the WHMP). Moreover, many 60-year rotation stands were not scheduled for this thinning entry, which could prolong the stem-exclusion stage. According to the literature, and our observations on WHMP lands, the stem-exclusion stage is unproductive and undesirable for most wildlife species, and the WHMP's techniques are intended to reduce the period spent in this stage. An additional complication in stand development is the appearance of a shade-tolerant conifer layer, which can compete with understory shrubs and herbs, and yet is desirable (if not too dense) in the long term for promoting a diverse multi-storied canopy.

The literature review generated a discussion of current issues in forest management that are relevant to the WHMP:

Can young harvest units on WHMP lands be managed for wildlife species that prefer some forest cover?

The WHMP aims to reduce the amount of time spent in the unproductive stem-exclusion stage. Can newer techniques further reduce the time in this stage?

Are there new methods or practices to better allow retention of understory herbs and shrubs through forest stand succession?

How can a balance be promoted between understory shrub/herb development and regeneration of shade-tolerant conifers and hardwood species?

The WHMP specifies traditional clearcutting and precommercial thinning (if needed) for 60-year rotation stands. It departs from traditional practices by providing 5% GTR at final harvest; for operational ease, this has been a single patch of trees left at the edge of the unit or in a wider buffer zone adjacent to a stream. The GTR was specifically intended to provide for expected snag replacement needs during the next rotation; there is no provision in the WHMP for other legacy trees. Commercial thinning in the WHMP is less specific but aims for 60-70 percent canopy closure at 40 years post-harvest, which is consistent with traditional light commercial thinning practices. It should be recalled from Section 2.1.1 that a number of 60-year rotation stands on the Lake Chaplain Tract were scheduled for traditional light commercial thinning, but only two units have actually been thinned. For several reasons these units are probably not characteristic of what the outcome would be in other Lake Chaplain stands: these units had well-developed shrub layers prior to harvest, unlike most other Lake Chaplain units, and they were fertilized with biosolids after thinning.

Current research suggests that higher levels of GTR will provide higher quality habitat for many wildlife species, including the WHMP's target species, and other forest birds, small terrestrial and arboreal mammals and amphibians. Promising options found in the literature for application to WHMP 60-year rotation stands include variable density thinning with provision for snags and CWD through the following rotation. The

literature provides computer simulations of the effects of dispersed and aggregated green tree retention (GTR), various thinning intensities, and the timing of entries into stands that may be applicable to the WHMP lands. However, results of field experiments and computer simulations are site-specific; that is, in addition to the treatment effects, the initial stand conditions will largely determine the outcome. Application of these techniques to other sites must consider how similar the starting conditions are to those reported in the literature before any predictions can be made regarding the results. It will be beneficial to track the future results of the field experiments described in Section 4.1.2 that have been initiated in Washington and Oregon to test the underlying hypotheses. Initial results on understory response and bird and small mammal population responses are very encouraging.

Current WHMP prescriptions rely on replanting harvest units primarily with one species, Douglas-fir, plus a small quantity of western red cedar. Planting densities were specified in the WHMP (though more seedlings have been planted on Lake Chaplain units) to reduce the need for precommercial thinning, adequately stock the site with conifer regeneration, and still allow understory recovery and development. However, in practice it appears that precommercial thinning may be required in many clearcut stands to enhance forage production regardless of initial planting densities. This is because western hemlock dominates most stands on WHMP lands, and natural regeneration of this species is common. The recent literature on wildlife habitat management advocates either replanting with a mixture of tree species, or managing the stand afterward to promote a greater variety of conifers and hardwood trees.

On both the Spada Lake and Lake Chaplain Tracts, variations on traditional commercial thinning can be used to mimic the creation of natural canopy gaps **(138)** by removing clusters of trees during harvest **(244)**. On lands where wildlife habitat improvement and wood production are the goals, forests should be opened to provide more light to understory vegetation when canopy closure reaches 80% **(239)**. The WHMP's commercial thinning prescription does not specify spacing or numbers of retention trees, but the current literature suggests that variable density thinning will enhance habitat value by increasing spatial heterogeneity **(244)**. Several shrub species have been shown to exhibit strong responses to thinning, and the subsequent increase in light input. Oregon grape, ocean spray, red huckleberry and salal all responded strongly to thinning intensity **(109)**. The degree of thinning also influenced shrub response; moderate thinnings, followed by heavy, then light thinning treatments were found to have the greatest impact on the probability of shrub flowering **(109)**. By reducing canopy closure to 60%, a cover of 40% salmonberry may result on appropriate soils **(239)**. In areas slated for harvest, old legacy shrubs, or pockets thereof, may need to be protected to ensure that large individuals are maintained into the next generation of forest **(109)**.

An economic analysis of the impacts of switching from traditional clearcut methods to options that retain more green trees is beyond the scope of this review. However, it is the focus of several computer simulations on various sites in the Pacific Northwest. The models that were used required input of site-specific variables to predict future growth and yield, and presumably this sort of analysis on WHMP lands would also need to be site-specific. It is likely that operational costs on WHMP lands would be highest for

dispersed GTR, lower for aggregated GTR, and lowest for clearcutting. When combined with snag creation, aggregated GTR appears to be operationally more efficient than dispersed retention.

5.2. Snag Management

Most second-growth stands on the Lake Chaplain Tract are approximately 80 years old and consist of mature sawtimber, with the largest tree diameters approaching 40 inches on many units. By preserving some of the large live trees during timber harvest, legacy trees can be carried from one rotation to the next. Clumping some of these live trees in areas of natural and created snags will benefit wildlife as well as increase ease of operation by reducing the restricted work area around the snags. These live trees clumped around snags will provide better protection for the snags as well as higher wildlife use (70, 102), and will moderate the microclimate, thus encouraging shrub growth (102) to create small pockets of refugia as the new stand develops.

Forests on the Spada Lake Tract are much younger than those at Lake Chaplain, so while providing larger snags for the needs of wildlife will prove to be more difficult, opportunities to enhance the growth rate in some areas can result in larger trees faster than under unmanaged conditions. Where feasible, commercial thinning can be used to reduce the stocking density, resulting in faster tree growth, and in areas where thinning is not possible, establishment of canopy gaps utilizing snag tree creation can speed the growth of remaining trees nearby, increase the understory development, and lead to multiple canopy layers, while at the same time providing clumps of primarily foraging-sized snags.

Nest trees are considered a limiting factor for most populations of PWP, so within managed forests, there is a need to ensure that these trees are provided, and not removed during forestry activities (168). Compilation of all pertinent research from the PNW region (42, 92, 101, 122, 140, 168, 236, 293, 309) indicates that snags averaging 37" dbh are necessary to meet the nesting requirements of the primary and secondary cavity nesting species present on WHMP lands (Table 5.2-1) and snags and decadent trees averaging 52" dbh are necessary for roosting habitat (Table 5.2-2). Trees near the lower end of this size range are available on four WHMP tracts, but on Spada Lake and Williamson Creek Tracts, only in old-growth stands. Some researchers of snags and cavity dependent species suggest that maintaining snags at a level similar to natural conditions is the most likely way to prevent many of these species from declining further, which could lead to threatened or endangered species listings and further encumbrance on land management within their habitat (64, 67). However, with the information provided by DecAID (67), we are given the opportunity to manage for specific species or groups of species, rather than trying to mimic natural, unharvested conditions. DecAID (67) reports that to meet 80% (the highest statistical level evaluated) of the nesting and denning needs of locally present cavity dependent species, snags ranging in size from 37" to 60" dbh are required. Resting and roosting requirements for the same group of species at the same threshold level require snags in the 44" to 79" range, thus further supporting the conclusions noted above regarding the average sizes of nesting and roosting snags. On WHMP lands, except on old-growth stands, only trees near the lower end of these

ranges are present. Snag creation aimed at the mean of these ranges would provide appropriate habitat for cavity-dependent species.

Table 5.2-1. Nest Tree Characteristics of Cavity Nesting Birds Common to the PNW.

Nest Tree Characteristics of PNW Cavity Nesting Species	Mean Tree DBH (in.)	Range (in.)	Mean Tree HEIGHT (ft.)	Range (ft.)	doc #
Downy Woodpecker (OR Coast Range)	15.4		26.4		140
Hairy Woodpecker (S. WA Cascades)	29.1		94.4		101
Hairy Woodpecker (OR Coast Range)	28.4	9.1 - 72.4	99.3	19.8 -211.2	140
Northern Flicker (S. WA Cascades)	50.3		152.8		101
Northern Flicker (OR Coast Range)	37.7	22.0 - 63.0	127.4	56.1-168.3	140
Pileated Woodpecker (Olympic Penn.)	40.0	26 - 61	128.0	56 - 184	122, 309
Pileated Woodpecker (OR. Coast Range)	26.4	18.5 - 41.3	87.5	46.2 -178.2	140
Pileated Woodpecker (SE Vancouver Is.)	32.3	26 - 38.6	72.6	55.4 - 89.8	168, 293
Pileated Woodpecker (SW WA.)	34.7		132.0		101
Pileated Woodpecker (W. Oregon)	27.0		87.0		122, 309
Pileated Woodpecker (W. Oregon)	28.0	15.7 - 54.3			92
Pileated Woodpecker (WA Coast)	39.8	25.6 - 60.6	129.7	56.1 - 184.8	42
Red-Breasted Sapsucker (S. WA Cascades)	30.0		72.6		101
Red-Breasted Sapsucker (OR Coast Range)	44.5	14.6 - 98.4	111.2	42.9 - 184.8	140
all 7 local species (S. Oregon Cascades)	31.1		81.2		236
ALL Primary Cavity Nesters (OR Coast Range)	34.5	13.6 - 98.4	105.9	9.9 - 316.8	140
ALL Secondary Cavity Nesters (OR Coast Range)	38.8	15.3 -104.3	97.7	9.9 - 227.7	140
average		37.2	99.0		

Table 5.2-2. Roost Tree Characteristics of Cavity Nesting Birds Common to the PNW.

Roost Tree Characteristics of the Pileated WP	Mean Tree DBH (in.)	Range (in.)	Mean Tree HEIGHT (ft.)	Range (ft.)	doc #
Pileated Woodpecker (W. Oregon)	44.1	15.7 -81.9			92
Pileated Woodpecker (Olympic Penn.)	59.0	15-122	120.0	36-207	122, 309
Pileated Woodpecker (W. Oregon)	44.0	16-82			122, 309
Pileated Woodpecker (WA Coast)	58.7	14.6 -121.7	120.5	36.3 - 207.9	42
average		51.5	120.3		

Estimates in the WHMP (Table 5.1) assumed that 2 snags/acre would need to be created initially, with 1 snag/acre required every 10 years thereafter. In practice, an average of 1.7 snags/acre has been created initially, and even now, 16 years after implementation began, replacement of far fewer than 1 snag per acre has been necessary because created snags are not falling down as fast as predicted by the WHMP, as Table 5.2-3 shows.

Table 5.2-3. Summary of Snag Monitoring at Lake Chaplain and Lost Lake.

SPECIES	SAMPLE SIZE	AVG DIAMETER (in.)	AVG HT. (in.)	AVG DECAY CLASS	AVG AGE (range) ¹	WILDLIFE USE
ALDER	6	15.0	48.7	2.60	9.4 (9.1-9.8)	50.0%
CEDAR	2	18.0	42.5	1.00	9.4 (9.4)	0% ²
DOUGLAS FIR	22	19.8	63.6	1.50	9.9 (9.4-11.3)	72.7%
HEMLOCK	32	17.0	50.2	1.44	9.7 (9.4-11.0)	81.3%
ALL SPECIES	62	17.9	54.6	1.57	9.7 (9.4-11.3)	79.0%

¹ Snags between 9 and 11 years old were evaluated to estimate % survival & use of snags at approximately age 10.

² One of the two Cedars evaluated was not killed as a snag, but rather partially stripped of bark to create opportunity for fungal infection to occur. This typically takes longer to see results than simply killing the tree.

These results show that at an age of approximately 10 years old, snags are still primarily in decay classes 1 & 2, which are sound, hard snags that are highly sought after by primary cavity excavators. In fact, of the 62 snags noted here that average about 10 years old, only 5% (3 snags - all alders, which are a fast decaying species) have broken off below the height at which they were initially topped, but are still standing as snags. Of all the snags monitored to date (706 out of the 4,925 snags created), nine (1.3% of those monitored) have broken off below the initial height of creation and none of those have fallen down completely. Incidentally, of the 9 that have broken off, 6 were girdled at a height of about 35', in an attempt to introduce defect and rot into the tree for habitat while still keeping the tree alive. All 9 of the trees that have been reduced in height are at

least 8 years old at this point in time, but are still standing. Snags are clearly lasting much longer and providing standing habitat longer than predicted by the WHMP. Some information from studies in the PNW (**140**) shows that snags greater than 20" dbh can last up to 125 years, and that snags less than 20" dbh are typically rotten stumps after 60 years. It appears that the estimates from the WHMP expected far greater replacement of snags than our own data, as well as current research, indicates will actually be necessary.

Large areas of the WHMP lands are currently set aside as passive management lands, including: approximately half of the Lake Chaplain tract (OMA, PMF, Buffer zones, etc.); nearly 80% of the Spada Lake Tract (due to steep slopes/water quality concerns and access issues); the entire Williamson Creek Tract and approximately 65% of the Lost Lake Tract. In total, approximately 60% of all WHMP lands are set aside as non-harvest stands, so that areas encumbered by WHMP prescriptions apply to less than half of the total land base.

Resource experts suggest that management of the snag resource occur separately for managed and unmanaged areas (**64**). Non-harvest areas such as those noted above can be maintained at higher densities of snags with larger size classes. Rationale for this split is partly due to a concern for operational issues surrounding timber management as well as the realization that under natural conditions, all areas would not have the same densities and sizes of snags due to differences in natural disturbance history.

Creation of several well-distributed large blocks of non-harvest land, maintained at higher densities with larger sizes of snags would help to better meet the needs of snag dependent species. These areas would also act as refugia for other old-growth dependent species. The following areas are already mapped as non-harvest blocks and would serve this purpose well: the Lost Lake Tract and adjacent PMF currently totals 256 acres, plans to harvest 10 acre units here would be abandoned; the large OMA on the east side of Lake Chaplain is approximately 166 acres of old growth and adjoining second growth where only snag management is currently practiced; the Horseshoe Bend area along the Sultan River is approximately 130 acres of PMF's, OMA's and buffer zones, and includes the Gold Camp unit, which is currently comprised of high densities of large snags, CWD and decadent trees. This 24 acre harvest unit would need to be removed from the managed inventory and added to this non-harvest block to provide continuity. By providing these large blocks of non-harvest lands, distributed across the Lake Chaplain and Lost Lake Tracts and containing larger snags at higher densities than the remainder of the tracts, high quality nesting, roosting and foraging habitat could be provided.

On the remainder of the non-harvest stands at Lake Chaplain and Lost Lake (OMA's, PMF's and buffer zones), snags would be created at higher densities and from larger trees than on the 60-year rotation stands. Again, this would provide well distributed, high quality habitat while reducing the operational issues associated with high densities of snags on harvest units. Snag requirements on 60-year rotation stands would be at reduced densities when compared to the non-harvest stands, but target sizes would be derived from the tables above, as numerous studies have noted that the mean diameters and heights should be the management targets (**20, 101, 123, 140, 309**).

Although the literature is less clear as to the density of snags required to meet the needs of local cavity-dependent species across the landscape, by providing these well distributed areas (OMA's, PMF's, buffer zones, and the 3 large blocks of non-harvest lands) with higher densities of larger snags, habitat values can be better retained than under the current prescriptions. Those documents that do provide specific densities for snags are summarized in Table 5.2-4, and provide a wide range of recommended densities.

Table 5.2-4. Snag Densities Suggested by the Current Literature.

Doc. #	Target Species	Snag DBH (in.)	Density (#/ac.)
309	Pileated Woodpecker - foraging	10-20"	>= 7.0
309	Pileated Woodpecker - foraging	20-30"	>= 3.0
309	Pileated Woodpecker - foraging	30"+	>= 2.0
112	Cavity Nesting Birds	11-50"	5.7
236	Primary Cavity Excavators	20"+	3-11; depending on site conditions
67	Cavity Dependent Species	>= 10"	36.4 including
67		>= 20"	14/acre

The Forest Service's management plan **(285)**, developed in response to the listing of the Spotted Owl as endangered, provides the following prescriptions:

retain 15%+ of the harvested area as green tree reserves; 70% of which should be clumps 0.2 to 1.0 ha in size, the remainder dispersed either individually or as small clumps < 0.2 ha in size. These clumps & dispersed groupings should be comprised of the largest, oldest, decadent or leaning trees and hard snags occurring within the unit. Snag management would primarily occur within these areas of green-tree retention **(43)**.

This is expected to meet the needs of 40% of the cavity dependent species on forest lands. Enacting a management plan such as this on WHMP lands would lead to larger green tree reserves where higher densities of snags could be provided and would allow existing WHMP prescriptions for snags to be met within harvest units (clumped along edges and buffers) thereby reducing operational issues during harvest.

Data from wildlife surveys in the region also provide guidance as to the densities of snags found on areas that contained nesting or roosting sites, but it should be noted that nesting and roosting areas have been shown in many studies to contain higher densities of snags and decadent trees and larger sizes of them than the surrounding forest **(42, 67, 140, 293, 330)**, so the intention is not to try to mimic that condition across the landscape, but to provide it in selected areas of high quality habitat.

Finally, stand management that results in open canopy conditions with mature conifers will promote diverse structures and understories that support more species and a greater abundance of cavity-nesting birds than found in closed-canopy forests with equal snag densities **(139)**.

5.3 Coarse Woody Debris Management

Comparisons of CWD studies in the literature with the WHMP's standards are hampered by differences in the units of measurement. Studies of CWD present results in several different ways: volume, biomass, or percent cover of the ground appear most frequently. Only a few are consistent with the format used in the WHMP, which prescribes density of pieces or logs by diameter and length. Most of the studies in this review examined CWD volumes or percent cover on managed vs. unmanaged forest stands, and reported the inputs from timber harvest and stand succession over time. The assumption in most studies is that wildlife species evolved with, and are adapted to, the quantities and sizes of CWD found in unmanaged stands (Table 4.3.1-1). This would be difficult to achieve in the 60-year rotation stands on WHMP lands, which are much younger than the stands in these studies. A more practical goal for the WHMP is to provide habitat for CWD-using wildlife species, but relatively few studies were found that clearly correlated wildlife abundance or well-being with numbers of logs on the ground.

It would be useful, given these constraints on our understanding of the literature, to use the DecAID Advisory Tool, described in Section 4.3.2. DecAID is based on a very comprehensive literature review and synthesis that is updated periodically for the purpose of guiding managers who want to provide CWD on their lands. DecAID recommends in general that if the objective is to manage for natural conditions rather than wildlife species, managers should provide varying distributions of CWD across the landscape. Expressed as percent ground cover, DecAID recommends that clumps of CWD should cover 5 to 19% of the ground, with a minimum size of 12.5 cm (5 inches), and distributed by size class as stated in Table 4.3.1-1.

5.4 Nest Structure Management

Boxes placed inconspicuously (**145**) and located at least 150' apart (**305**) are more likely to reach full reproductive potential and reduced predation, respectively. Boxes that successfully fledge young are more likely to be used again the following year, so ensuring that they are cleaned and repaired as necessary is important. A minimum density of 5 potential cavity trees per acre within 0.5 miles of wetlands is recommended to provide for the nesting needs of cavity nesting waterfowl.

Nest checks should be conducted soon after the peak of nesting, and will produce more reliable results than those conducted at the end of the season but due to difficulty in counting membranes, and the potential that some may have been carried out of the nest, adding 1 to the membrane count will produce the most accurate estimate of fledgelings (**147**). Females using the same box the following year begin nesting an average of 13 days earlier and have larger clutches (**144**). As nest parasitism occurs more frequently with visible boxes, more eggs are wasted by not hatching, but overall, the boxes produce the same number of fledglings as hidden boxes (**145**). Rates of nest box parasitism were found to be directly related to the location of the box, and not related to scarcity of available boxes (**145**).

5.5 ROW Management

The information presented in the literature on ROW management reviewed for this document has been in use on WHMP lands for over 10 years. Mowing currently occurs after the end of July, which also allows the existing grass/forb layer to produce seeds, thereby greatly reducing the amount of hand seeding required. Additionally, mowing after the nesting season has occurred reduces the likelihood that ground nesting birds and small mammals will be destroyed in the process, since they will have left the nest by that point of the season.

5.6 Deer Forage Management

The WHMP's current prescriptions for clearcutting are still effective at producing forage in the early stages of forest succession, and the District's review did not reveal any methods that would help keep these areas in a permanently open forage-producing stage, e.g. meadows. Silviculture alternatives for managing forest succession, described in Section 5.1, offer the possibility of prolonging the availability of understory shrub and herb layers. Modifications of this sort would likely benefit deer and other species that use forest openings.

Review of information related to deer home ranges offers guidance on planning for forage, hiding cover and thermal cover. Essentially, these resources must be available in a very small area – low-elevation resident deer on Vancouver Island had home ranges under 1.9 km² and did not move far from their accustomed sites even when their preferred habitats were not ideal following logging (see Section 4.6). Strong site fidelity may limit the ability of deer to respond to rapid habitat changes, or alternatively may limit their ability to find sites outside their normal range that have been improved by management. Management of young forests to improve winter habitat suitability for deer may only benefit deer in the immediate vicinity, at least initially. There may be a lag time before the population responds.

WHMP 60-year rotation units are sufficiently small and well-interspersed that it is likely that adequate resources will be available at the Lake Chaplain Tract, if the current harvest schedule is followed. The young second-growth forest stand at the Lost Lake Tract that was precommercially thinned in 1991 responded with increased shrub coverage and could possibly provide more forage production through follow-up silvicultural treatments.

The Spada Lake Tract has approximately 390 acres dedicated to early successional species, and about 100 acres have been lightly commercially thinned so far (see Section 2.1.1). The response of these stands to opening the canopy has been some scattered forage production and an increase in shade-tolerant conifer seedlings, but post-harvest gap openings currently being implemented are expected to produce more forage. Adjacent DNR lands do not offer much suitable foraging habitat for black-tailed deer and future management will be passive in the Spada Lake area.

5.7 Riparian Habitat, Streams and Wetlands

The WHMP's concerns focus on buffer zones for streams and wetlands and activities (usually road construction or timber harvest) that are allowed in buffer zones. The WHMP prescribes fixed-width buffer zones related to the classification of the streams or wetlands they are intended to protect, but without regard to the characteristics of the adjacent upland habitats, the wildlife species that are likely to use the riparian habitat, or the functions that the riparian or wetland buffer zones perform. The guidelines reviewed by the District indicate that management of these zones ought to take these functions into consideration.

The WHMP prescribes monitoring of buffer zones post-harvest, but does not indicate any active management. At the time it was written, the WHMP prescribed buffer zone widths that were wider than standard forest practice requirements, and included Type 5 waters (which are generally intermittent or seasonal, or lack a well-defined channel) in its protection. As described in Section 4.7.2, we did not find agreement on buffer zone widths or allowable activities in buffer zones. Under the current Forest Practices interim rules, protection has increased for fish-bearing waters and the rules use better science to determine buffer zone width, but protection for former Type 5 waters is limited to equipment restrictions. Forested wetlands are still not given much protection under Forest Practices, relative to Snohomish County's rules, or guidelines recommended by WDFW and DOE. However, the WHMP is a mitigation plan, and mitigation plans typically offer more than the minimum requirements stated in Forest Practices or other regulations, especially if scientific guidelines and opinions indicate this would be in the best interests of the target species and functions. Using this reasoning, the District's biologists and foresters have dealt with the protection of forested wetlands and intermittent streams on a case-by-case basis in the past wherever logging road construction or timber harvest require activity in the vicinity of these minimally protected resources.

An unquantified amount of riparian habitat is included in WHMP lands, especially along the many streams in the Spada Lake Tract, and therefore this habitat was not factored into HEP calculations. The WHMP has not focused on manipulating riparian forest canopies or ensuring that riparian zones will contribute conifer CWD into aquatic habitats, but it is expected that conifers will naturally dominate some riparian stands over time.

Most of the literature review of wetlands management dealt with restoration techniques that are performed to compensate for development activities in wetlands. Development is not an issue on WHMP lands because most of the WHMP's wetlands are in fairly pristine condition, so wetland restoration has not been a focus of the WHMP. Wetlands are mapped and monitored by District staff, but active management has never been prescribed. The District is currently involved in identifying previously mapped and unmapped wetlands and evaluating their functions (Revised Study Plan 9: Wetland Surveys).

6.0 CONCLUSIONS

Section 4 of this report presents a synthesis of the findings reported in the annotated bibliography (Appendix 1), and their relevance to the implementation of the WHMP is described in greater detail in Section 5. Appendix 4 is a tabular summary of current management under the WHMP and related potential management alternatives found in the scientific literature. Information in Appendix 4 is discussed more fully in Section 5 of the report.

Many options for timber harvest, silvicultural treatments and other management techniques were found in the literature review, and it is clear that the choices of specific treatments must be tailored to the opportunities and operational constraints of the forest stands in question, economics of the options and to the management objectives for those stands. Regardless of the specific management techniques selected as the result of this review, the WHMP remains an adaptive management tool. Many highly relevant research programs are ongoing, and only computer simulations, experimental designs and/or early results of experiments were available for review. Because of the potential benefits these studies may provide to the Jackson Project's habitat management program, the co-licensees will continue to monitor the progress of ongoing studies reported in this review. Important new findings that may improve the implementation of the WHMP will be evaluated, and if any of them are adopted, this information will be shared with the Jackson Project's agency reviewers.

Appendix 1

Annotated Bibliography

Introduction

Relicensing Study Plan 6 - Habitat Management Methods Literature Review and Evaluation - was undertaken by District staff to identify advances in wildlife habitat management techniques that may be relevant and useful to an evaluation of the Jackson Project's Wildlife Habitat Management Plan (WHMP 1988). A copy of Study Plan 6 can be found at the Jackson Project relicensing website:

http://www.snopud.com/Content/External/Documents/relicensing/Relicense/RSP/Revised_Study_Plan_091206_Modified.pdf

District staff created a database listing a large number of technical studies, management plans and procedures that appeared to have some application to an evaluation of the WHMP's management techniques, and rated the relevancy of each reference to the goals and objectives of the WHMP and its management techniques. To be selected for evaluation references had to be:

1. related to Pacific Northwest ecosystems, i.e. western Oregon, Washington, British Columbia.
2. currently applicable, preferably dated after 1990.
3. consistent with the WHMP's stated goals and objectives, and relevant to the current management techniques. Review topics include:
 - Old growth forests (including management of stands for old growth characteristics)
 - Riparian habitat
 - Streams, wetlands and buffer zones
 - Second growth forest/overstory management (including gaps and reserve green trees)
 - Second growth forest/understory management
 - Snags and gaps
 - Coarse woody debris
 - Right-of-way management
 - Nest structures
 - Deer forage

The list of references was sent to reviewers on May 6, 2007 with a request that they review the citations and add any important references that they believed ought to be included in the evaluation.

Subsequently District staff added some citations to the list and summarized the information in each reference that appears to be relevant to an evaluation of the WHMP. The result of this process is the attached annotated bibliography. References included in the bibliography comprise the currently available information that staff found is relevant to the WHMP's objectives and management techniques. The evaluations of relevance are not a comment on the importance of the research contribution or the scholarship involved in each reference; rather, the evaluations are District staff's opinions of how applicable the results or

recommendations in each reference are to the District's current habitat management program. References were rated as follows:

- Relevant – Studies that are current, geographically similar, and offer management recommendations that may have direct application to the WHMP.
- Somewhat relevant – Studies that offer useful information on topics that are included in the WHMP, that might potentially be extrapolated into management guidance.
- Not relevant – Studies that may be out of the geographic range of interest, or don't offer management recommendations that would be useful to the evaluation of the WHMP.

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Coarse Woody Debris

43	<p>Aubry, K.B., Raley, C.M. 2002. The pileated woodpecker as a keystone habitat modifier in the Pacific Northwest. In W.F. Laudenslayer, Jr. (and others), tech. coords. Proceedings of the Symp. on the Ecology and Management of Dead Wood in Western Forests. PSW-GTA-181. Albany, CA: US Forest Service, Pacific SW Res. Stn. pp. 257-274.</p> <p>1 - Very Relevant to Jackson WHMP</p> <p>Recommendations for forest management in matrix lands covered by the NW Forest Plan:</p> <p>Table 3 provides Forest Service guidelines for retention of logs during timber harvest on matrix lands in the Northwest Forest Plan:</p> <ul style="list-style-type: none"> • In western Washington leave 240 linear feet of logs/ac \geq 20 in diameter. Logs < 20 ft in length cannot be credited toward this total. • Decay class 1 and 2 logs can be counted towards these totals. Down logs should reflect the species mix of the original stand.
134	<p>B.C. Ministry of Forests. 1992. Maintaining marten habitat in managed forests. Fish and Wildlife Branch, Thompson Nicola Region and Wildlife Branch, Victoria, B.C.</p> <p>2 - Somewhat Relevant to Jackson WHMP</p> <p>Guidelines based on studies conducted in the dry, pine dominated Montane Spruce zone of eastern BC (Okanagan).</p> <p>The document has three parts:</p> <ol style="list-style-type: none"> 1. Minimum habitat requirements for maintaining marten in the Montane Spruce and dry, pine dominated Englemann Spruce Sub-alpine fir zones. 2. Timber harvest guidelines for maintaining marten habitat at the landscape level within this forest type. 3. Site-specific silvicultural guidelines for maintain marten habitat following timber harvest within this forest type. <p>Summary tables from each part are attached to this citation.</p> <p>Silvicultural Guidelines:</p> <p>CWD is the single most important attribute selected by marten. Salvage the largest diameter CWD on the stand, uniformly distributed through the unit. Both sound and decayed CWD should be saved. Pile logging debris as a supplement.</p> <p>Wildlife trees must be at least 30 cm dbh and 3 m or more in height. Live trees with cavities, snags and tall hollow stumps are used.</p>
329	<p>Brown, E. R., tech. ed. 1985. Management of Wildlife and fish habitats in forests of western Oregon and Washington. U.S. Forest Service ubl. No. \$6-F&WL - 192-1985. Portland, OR.</p> <p>1 - Very Relevant to Jackson WHMP</p> <p>Chapters in this document provide the basis for WHMP management techniques dealing with timber harvest, silviculture, deer forage, snag and coarse woody debris management.</p>
201	<p>Bull, E.L. 2002. The value of coarse woody debris to vertebrates in the Pacific Northwest. Gen. Tech. Rep. PSW-GTR-181. USDA Forest Service. Pp. 171-178.</p> <p>3 - Not Relevant to Jackson WHMP</p>
206	<p>Bunnell, F.L., Houde, I, Johnson, B., Wind, E. 2002. How dead trees sustain live organisms in western forests. Gen. Tech. Rep. PSW-GTR-181. USDA Forest Service. Pp.291-318.</p> <p>2 - Somewhat Relevant to Jackson WHMP</p> <p>Ensure sustained provision of dying and dead wood. Retain trees and snags of both</p>

	<p>hardwoods and favored conifer species, retain a range of size and age classes of dead wood, ensure that large trees or snags are retained, don't do the same thing everywhere. Retention of trees in patches reduces safety risks of snag retention and windthrow, and facilitates retention of a range of size and decay classes. It also concentrates recruitment of down wood. Any single approach will disadvantage some group of species, so a range of practices is preferable if a range of species is to be sustained in an area.</p>
210	<p>Bunnell, F.L., Houde, I., Johnson, B., Wind, E. 2002. How should we spatially distribute dying and dead wood? Gen. Tech. Rep. PSW-GTR-181. USDA Forest Service. Pp. 739-752.</p> <p>2 - Somewhat Relevant to Jackson WHMP</p> <p>Review article describing mammal use of CWD and pros and cons of its distribution of harvested units. Aggregations are used by several small mammals, both predator and prey. More evenly dispersed retention favors some fungi and bryophytes. "Because there is no unequivocal best way to distribute logging residuals, the wisest approach is not to do the same thing everywhere." Distribution can be manipulated by retaining live trees to fall after harvest.</p> <p>Recommendations:</p> <p>Logs as small as 6 cm are used by shrews, but in some forest types, larger mammals prefer significant amount (100 – 200 cu m/ha or more) and sizes (>50 cm diameter) of downed wood. Mammals such as marten, fisher and black bear require scattered, large pieces, 50 to 100 cm diameter.</p>
197	<p>Butts, S.R., McComb, W.C. 2000. Associations of forest-floor vertebrates with coarse woody debris in managed forests of western Oregon. J. Wildl. Manage. 64(1):95-104.</p> <p>2 - Somewhat Relevant to Jackson WHMP</p> <p>Field study in western OR. CWD volume ranged from 14 to 859 cu m/ha. Stands with the lowest volumes had fewer salamander captures than stands with higher CWD volume. Contrasts these findings with OR state regulations (1.5 cu m/ha CWD) and federal guidelines (37 cu m /ha.) "Our study suggests that current management guidelines for CWD retention may not provide adequate habitat for forest-floor vertebrates that depends on this component of the habitat." Suggest that retention of CWD in managed stands should model CWD found in natural stands. In western Cascades, avg. 248 cu m/ha in natural young stands <80 yrs old, 148 cu m/ha in 80-120 yr old stands (Spies et al 1988). Suggest that CWD retention in the range of 100-300 cu m/ha is more likely to provide adequate CWD for terrestrial salamanders.</p>
27	<p>Carey, A.B., Curtis, R.O. 1996. Conservation of biodiversity: a useful paradigm for forest ecosystem management. Wildl. Soc. Bull. 24(4):610-620.</p> <p>1 - Very Relevant to Jackson WHMP</p> <p>Proposes stages of forest ecosystem development in the Western Hemlock zone:</p> <ul style="list-style-type: none"> Ecosystem initiation Competitive exclusion Understory reinitiation Developed understory Botanically diverse Niche diversification Fully functional (managed) Old-growth <p>Compares them with Brown (1985) stages, e.g. Competitive exclusion is similar to closed sapling-pole-sawtimber, and Developed understory is similar to large sawtimber. Carey's descriptions are useful because they describe benefits to wildlife in addition to describing canopy species size/density. He proposes biodiversity treatments for each stage, including variable density thinning with and without CWD and snag augmentation.</p> <p>Management foundations of the biodiversity pathway (sounds very zen-like):</p> <ol style="list-style-type: none"> 1. Conserve biological legacies during harvest and regeneration, including soil organic matter, litter, CWD, snags, forbs, shrubs, mycorrhizal fungi.

	<p>2. Plant Douglas-fir at wide spacing; provide for natural or artificial regen of hemlock, red cedar, grand fir, western white pine. Concurrent regeneration of red alder, bigleaf maple, evergreen hardwoods.</p> <p>3. Minimize area and time in the competitive exclusion stage through PCT and VDT (heavier than conventional commercial thinning).</p> <p>4. Ensure diversity and niche diversification in later stages through subsequent thinnings with CWD augmentation.</p> <p>5. Use extended rotations (80-130 yrs).</p> <p>Minimize site prep to reduce invasion by excessive red alder. Control dense shrub layers as needed to secure conifer establishment; in closed-canopy second growth conifer stands, use biodiversity thinnings to maintain or restore diversity.</p> <p>Suggests using 2+ densities in the initial VDT. E.g., retain 309 tpa and 185 tpa in a 2:1 ratio on a 0.2 ha scale in a 30- to 50-year-old stand of 10- to 50-cm dbh trees.</p> <p>Suggests 2 additional VDTs to leave CWD to meet target of 15% cover on the forest floor, maintain understory. CWD size range 10 to 100-cm dbh..</p> <p>Suggests the biodiversity thinnings will produce approximately the same long-term wood production resulting from conventional rotation length, but cost is the reduction in present net value associated with extended rotations..</p>
160	<p>Corn, J.G., Raphael, M.G. 1992. Habitat characteristics of marten subnivean access sites. <i>J. Wildl. Manage.</i> 56:442-448.</p> <p>3 - Not Relevant to Jackson WHMP</p> <p>Describes the importance of snags, stumps and logs in providing denning habitat in the central Rocky Mountains.</p>
271	<p>Daniels, L.D., Dobry, J., Klinka, K., Feller, M.C. 1997. Determining year of death of logs and snags of <i>Thuja plicata</i> in southwestern coastal British Columbia. <i>Can. J. For. Res.</i> 27:1132-1141.</p> <p>3 - Not Relevant to Jackson WHMP</p>
69	<p>Duncan, S. 2002. Dead wood all around us: think regionally to manage locally. USDA Forest Service PNW Res. Stn. Science Findings 42. March 2002. 6p.</p> <p>1 - Very Relevant to Jackson WHMP</p> <p>Summary of interview with J. Ohmann and K. Waddell regarding the compilation of a dead wood database. This is "the most comprehensive study yet available of dead wood across both managed and unharvested forests of all ownerships in the PNW." The compilation included data from more than 16,000 field plots across 9 habitat types.</p> <p>Key points include:</p> <p>Large snags were more than 2x as dense in unharvested forests than harvested areas.</p> <p>Average densities of snags at least 10" dbh ranged from 3 to 91 tpa.</p>
199	<p>Feller, M.C. 2003. Coarse woody debris in the old-growth forests of British Columbia. <i>Environ. Rev.</i> 11(s1):S135-s157.</p> <p>3 - Not Relevant to Jackson WHMP</p> <p>Synthesis of literature and data collected by the author on CWD in old-growth forests of British Columbia.</p>
120	<p>Graham, R.L., Cromack, K., Jr. 1982. Mass, nutrient, content, and decay rate of dead boles in rain forests of Olympic National Park. <i>Can. J. For. Res.</i> 12:511-521.</p> <p>3 - Not Relevant to Jackson WHMP</p> <p>Hemlock mortality in open- and closed-canopy forests of the Olympic peninsula was due</p>

	<p>mainly to windthrow. The open forest contained 120 t/ha of dead bole wood; the closed forest contained 161 t/ha. Hemlock boles decayed more rapidly than the larger spruce boles</p>
121	<p>Gyug, L.W. 1993. Furbearer and prey use of logging debris piles in clearcuts: progress report 1992/3. Consultant report prepared for Ministry of Environment, Penticton.</p> <p>3 - Not Relevant to Jackson WHMP</p> <p>Study area was interior southern BC. Report motivated by concern that burning of logging debris might lead to long-term habitat losses for marten.</p> <p>Marten and weasels use young clearcuts with high levels of logging debris (>1 spot-pile/ha or >1 roadside-logging windrow per block) more than clearcuts with no debris piles or low levels of piles. Marten prefer the longer windrow piles resulting from roadside logging.</p> <p>Snowshoe hare, yellow-pine chipmunk, deer mouse and lynx use of these young clearcuts not affected by retention of logging debris piles. Red squirrels and red-backed voles (a favorite prey of marten and weasels) did not use young clearcuts.</p>
244	<p>Hagar, J. 2006. Key elements of stand structure for wildlife in Pacific Northwest conifer forests. In Harrington, T.B., G.E. Nicholas, tech. eds. Managing for wildlife habitat in west-side production forests. Gen. Tech. Rep. PNW-GTR-695. Portland, OR:USDA Forest Service, Pac. NW Res. Stn. Pp.35-48.</p> <p>1 - Very Relevant to Jackson WHMP</p> <p>Review article discusses key features:</p> <p>Large trees, e.g. wolf trees, remnant old growth trees. If evenly dispersed, large trees in otherwise unsuitable (i.e.harvested) areas can facilitate movement of forest interior spp. Options for recruiting, developing and maintaining large trees include retaining green trees at harvest, and growing them at reduced stand density to provide growing space for larger limbs and deeper crowns.</p> <p>Large dead wood. Size and decay stage matter. Habitat value increases with diameter, and a diversity of decay stages of snags and logs. Avg. diameter of snags used by all wildlife spp for nesting or denning exceeds 50 cm. Chipmunks selected logs that have larger avg diameters than randomly available wood to use at travel paths. Den sites for large animals (e.g. bear) are limited to logs of >80 cm.</p> <p>Current guidelines for augmenting volumes of woody debris in managed forests may be inadequate to maintain populations of all associated spp. (Rose et al 2001, Wilhere 2003). At least 10 snags >25 cm dbh per hectare recommended, (Hayes and Hagar 2002, Mellen et al 2006). Avg. diameter of snags used by cavity-using spp is >56 cm (Mellen et al 2006).</p> <p>Management strategy for spp associated with dead wood should ensure spatial and temporal continuity of habitat.</p> <p>**Retain existing large snags and logs during timber harvest</p> <p>**Plan for future recruitment of dead wood. Retained trees can be clumped in patches for safety and operational ease.</p> <p>**Use advisory tools, DecAID (Mellen et al 2006) and Coarse Wood Dynamics model (Mellen and Ager 2002) to plan dead wood management.</p> <p>Floristic diversity, in particular the presence of shrubs and hardwood trees, especially important for wildlife diversity. Literature shows consistent patterns of positive correlations b/n birds and abundance and distribution of hardwoods in conifer forests.</p> <p>"Hardwoods may be preferred by many species [of cavity-nesting birds and mammals] because wood properties and decay patterns often result in softened heartwood that is easily excavated, while the sapwood remains unaffected by decay...In contrast, sapwood of Douglas-fir snags often decays by the time heartwood is sufficiently softened for cavity excavation...Because of these differences, hardwoods can provide suitable cavity sites at</p>

	<p>relatively smaller diameters than conifers (Bunnell et al. 1999).</p> <p>Management of hardwoods should begin early in stand development. Controlling density at an early age, before canopy closure, can help to maintain diverse stand structure throughout the life of a stand (Tappeiner et al. 2002). Although shrubs may dominate early succession, it is unlikely that clear-cutting can be used to immediately create quality habitat for shrub-associated wildlife spp.</p> <p>Commercial thinning has the potential to increase habitat value for shrub-associated wildlife. (citations) Cover and productivity of shrub understory may respond positively to thinning. Variable density thinning may further enhance habitat by increasing spatial heterogeneity. Leave trees may be selected on the basis of characteristics such as cavities, large limbs. Etc. rather than spacing.</p> <p>Sites for shrubs and hardwoods minimize impacts of timber production may include seeps, wet depressions, small wetlands, riparian areas, road edges, landings, root rot pockets. Intentionally-managed canopy gaps could serve as sites for large trees, snags and floristic diversity.</p>
129	<p>Hansen, A.J., Spies, T.A., Swanson, F.J., Ohmann, J.L. 1991. Conserving biodiversity of managed forests. <i>Bioscience</i> 41(6):382-392.</p> <p>2 - Somewhat Relevant to Jackson WHMP</p> <p>Natural disturbance in unmanaged forests maintains structural complexity within stands, and this complexity promotes plant and animal diversity. This paper has a good discussion of the role natural disturbance and forest succession, including some data on snag and cwd densities in unmanaged forests.</p> <p>Recommendations for managed forests with biodiversity goals:</p> <p>Retain structural legacy from the preharvest stand, e.g. large trees in cutting units. Extend rotation ages. Produce new large trees, snags and CWD over the course of forest rotation. Preserve herb/shrub stage.</p>
131	<p>Harmon, M.E. 1992. Long-term experiments on log decomposition at the H.J. Andrews Experimental Forest. Gen. Tech. Rep. PNW-GTA-280. Portland, OR: Pacific Northwest Research Station, USDA Forest Service; 28 p.</p> <p>2 - Somewhat Relevant to Jackson WHMP</p> <p>This report describes the establishment and initial conditions of a long-term experiment to study the role of decomposing CWD in nutrient cycling in forest ecosystems of the Pacific Northwest.</p> <p>Three hypotheses will be tested:</p> <ol style="list-style-type: none"> 1. processing rates decrease with the decay resistance of the heartwood, 2. processing rates increase with the rate the log is colonized by decomposers, 3. insects are crucial in starting colonization <p>Four species - Douglas-fir, Pacific silver fir, western hemlock and western redcedar - were set up in experiments. Logs are 45 to 65 cm in diameter and 5.5 meters long.</p> <p>Early results (4 years after setup) include:</p> <ol style="list-style-type: none"> 1. Western hemlock decomposed slower than Douglas-fir for the first 3 years, but in the long terms the opposite is expected to occur. 2. Decomposition of Pacific silver fir was more rapid than expected (9% of the mass lost between the third and fourth years). 3. Western hemlock logs decomposed slower than expected.

	<p>4. Douglas-fir and western redcedar are decomposing at rates close to those observed in chronosequences.</p> <p>5. A large variety of insects and decomposers cause the start of decay process.</p> <p>6. Excess moisture limits respiration of decomposers.</p> <p>7. Fungal fruiting bodies are the major pathway through which nitrogen is exported from logs during early decomposition.</p>
130	<p>Harmon, M.E., Franklin, J.F., Swanson, F.J., Sollins, P., Gregory, S.V., Lattin, J.D., Anderson, N.H., Cline, S.P., Aumen, N.G., Sedell, J.R., Lienkaemper, G.W., Cromack, K. Jr., Cummins, K.W. 1986. Ecology of coarse woody debris in temperate ecosystems <i>Advances in ecological research</i> 15:133-302.</p> <p>2 - Somewhat Relevant to Jackson WHMP</p> <p>The paper reviews rates of input and loss of CWD to various ecosystems, including conifer-dominated systems, decomposition processes, and functions of CWD in ecosystems. Functions described in this paper include nutrient cycling, habitat, and influences on geomorphic processes, especially in streams. Concerns over effect of human activities on CWD and CWD-related processes are discussed but there are no management recommendations.</p>
225	<p>Hartwig, C.L., Eastman, D.S., Harestad, A.S. 2006. Characteristics of foraging sites and the use of structural elements by the pileated woodpecker (<i>Dryocopus pileatus</i>) on southeastern Vancouver Island, British Columbia, Canada. <i>Ann. Zool. Fennici</i> 43:186-197.</p> <p>1 - Very Relevant to Jackson WHMP</p> <p>Until recently, feeding habitat had not been considered as important as nesting habitat for PWP because any woody debris >18 cm was considered available for feeding year round.</p> <p>Additional research points to selection for much larger trees than previously thought in many areas, including WA.</p> <p>Snags and defective trees used for foraging were larger, more decayed, and had significantly less bark and fewer limbs than those not used.</p> <p>Used snags and defectives were significantly larger in mean dbh than unused ones. The numbers of snags used in the two largest dbh classes were significantly greater than those in all other classes of snags and defectives that were used.</p>
102	<p>Knutson, K.L. and V. Naef. WDFW, June 1995. <i>SNAGS: Management Recommendations for Washington's Priority Habitats</i>. 137p.</p> <p>1 - Very Relevant to Jackson WHMP</p> <p>Bernice, this doc has brief mentions of Riparian buffers, CWD, etc.</p> <p>Mike's review:</p> <p>Westside forests containing 4 snags/acre or more that are greater than 20" dbh are considered Priority Habitat.</p> <p>Approx. 102 species in Washington use snags; 56 species nest or den solely in cavities within dead or dying trees.</p> <p>*** the following 14 cavity-nesting species are Priority Species,</p> <p>***** Northern Spotted Owl is listed as endangered;</p> <p>***** The Pileated WP and Vaux's Swift are both Candidate Species for listing.</p> <p>***** The remainder are Priority Species, considered for listing:</p> <p>flamulated owl, purple martin, western bluebird, fisher, wood duck, Barrow's Goldeneye, common goldeneye, bufflehead, hooded merganser, marten and western gray squirrel.</p> <p>*** Natural ecosystems should provide the model for determining suitable numbers and</p>

	<p>characteristics of desired snags, i.e. average density and size found in unmanaged old-growth forests should serve as the targets for snag retention. Diverse, abundant and stable communities of snag-using species occur in unmanaged forests, particularly late-successional stands. Past use of minimums as standards has resulted in less habitat being provided than necessary, and hence continued population declines.</p> <p>Only old-growth stands were found to support 100% of the maximum potential population of primary cavity-nesters, so managing for averages based on these areas provides the best hope of retaining and increasing populations of snag dependent wildlife. Without such measures, the 56 cavity-dependent wildlife species will likely continue to decline in number, and may be listed as threatened or endangered.</p> <p>*** Models (i.e. Thomas et al. 1979) that have been used for the past 15 years have several problems, they only consider nesting requirements, not foraging or roosting and therefore appear to underestimate the number of snags needed.</p> <p>*** Additionally, these models may underestimate by assuming that meeting the needs of primary cavity excavators also meets the needs of other snag dependent species. In fact, secondary users may be more sensitive to snag densities than the primary nesters.</p> <p>Snags should be retained both individually and in clumps (including live trees and existing snags), if possible, and should be well distributed across the landscape. Clumps reflect the natural pattern of trees dying in patches from insects, small fires and disease. Clumping may also help to reduce impacts on logging operations.</p> <p>Artificial snag creation should not take the place of retaining existing snags.</p> <p>Snags in riparian areas are particularly important because several cavity-nesting species (wood duck, osprey, pileated wp) preferentially breed close to streams and wetlands.</p> <p>As a group, cavity-excavators prefer trees greater than 24 m (79ft) tall.</p> <p>Snags in decay stages 2-4 (7-125 yrs old) are most commonly used for nesting. At the start of stage 4 (51 years old) nesting use begins to decrease.</p> <p>Douglass-fir are the most commonly used nesting tree, but are also the most available in larger size classes. They tend to decay from the outside in and are favored by weak excavators. Hemlock are more susceptible to heart rot and are therefore more attractive to woodpeckers, but stand for a shorter period.</p> <p>Hardwoods tend to grow in irregular shapes and can produce cavities in the trunk or branches even while alive. Since they are much less common than conifers, they are particularly valuable wherever they are found.</p> <p>Audubon Society Christmas bird counts over 30 years have shown a decrease in the populations of the downy and hairy woodpeckers, as well as the northern flicker.</p> <p>Diameter is the most important distinguishing characteristic of snags used for nesting and foraging. Snags and decadent trees greater than 38 cm (15in) dbh are used by some species for nesting and foraging, larger diameter snags (>51 cm/20in dbh) are preferred and offer optimal nesting and foraging conditions. Taller snags are also preferred (>18m/59ft).</p> <p>When creating snags, trees should be topped (chainsaw was shown to be the most effective method) 15-25m (50-82ft) above the ground. Wind firm conifers at least 51 cm (20 in) dbh should be selected. Live trees should be reserved around the created snags to provide better protection for the snag as well as higher wildlife use.</p>
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	<p>Retaining live green trees around created snags in harvested areas also moderates the microclimate and thus encourages seedling and shrub growth as well as increasing wildlife use of the clearcut.</p> <p>Contrary to common opinion, retained trees do not act as a source of pests for the new developing forest. They actually serve as refugee and inocula for invertebrate fauna and mycorrhiza-forming fungae that are essential components of a new stand.</p> <p>Riparian Habitat Area Minimum Widths are reported in Table 4 of the document.</p> <p>Salvage logging should not be conducted if an area is being managed for the benefit of wildlife.</p> <p>Link below is to App B showing averages and minimums for snags in the Western Hemlock series (when using this table, Mark Hitchcock reports the following, Lake Chaplain is 70% site class 2, 25% class3 and 5% class 1; Spada is 60% site class 3, 30% class 4, and 10% class 5)</p> <p>****SEE ALSO Y:\Regulatory Affairs\WILDLIFE\Relicensing_Study_Plans\SP6 Literature Review\Supporting Documents\Summary of Findings SP6 - Snags.xls</p> <p>AND</p> <p>Y:\Regulatory Affairs\WILDLIFE\Relicensing_Study_Plans\SP6 Literature Review\Supporting Documents\102 WDFW Snag Mgmt Recommendations App B.pdf</p>
122	<p>Lewis, J. C. and J. M. Azerrad. 2003. Pileated Woodpecker. Pages 29-1 – 29-9 in E. Larsen, J. M. Azerrad, N. Nordstrom, editors. Management Recommendations for Washington's Priority Species, Volume IV: Birds. Washington Department of Fish and Wildlife, Olympia, Washington, USA. 1 - Very Relevant to Jackson WHMP</p> <p>Most nests are in hard snags with intact bark and broken tops, or live trees with dead tops.</p> <p>PWP may use up to 11 roosts over a 3-10 month period.</p> <p>Cedar are often preferred as roost trees due to natural hollowing.</p> <p>Mature and OG forest are considered high quality habitat, but forests as young as 40 years are used if large residual snags are present.</p> <p>Shelterwood cuts and clearcuts are occasionally used if substantial foraging habitat is retained.</p> <p>Deciduous riparian habitat is used for foraging activities.</p> <p>Large snags are preferred foraging substrate, possibly because they harbor more insects and larvae than smaller snags.</p> <p>CWD is rarely used for foraging in wet coastal forests.</p> <p>Forest fragmentation may reduce population density and increase vulnerability to predation as the birds are forced to fly between fragmented forest stands.</p> <p>Management activities should focus on providing and maintaining large snags and large decaying live trees for nesting and roosting.</p> <p>Retaining snags and decaying live trees provides suitable nesting and roosting structure for a</p>

	<p>longer period than retaining/creating only hard snags.</p> <p>Trees, snags and stumps with existing PWP nest cavities and foraging excavations should be retained.</p> <p>Uneven-aged forest management can help to provide large trees and suitable canopy closure to maintain suitable nesting and roosting structure for PWP.</p> <p>Defective and cull trees should be retained during harvest operations.</p> <p>Extending harvest rotations may be one of the most effective means of providing large snags.</p> <p>Average values of given habitat components should be used as management goals.</p> <p>"Adequate snag densities are defined as the combination of nesting, roosting and foraging snag numbers"</p> <p>*** Recommendations: see supporting link</p>
208	<p>Maguire, C.C. 2002. Dead Wood and the richness of small terrestrial vertebrates in southwestern Oregon. Gen. Tech. Rep. PSW-GTR-181. USDA Forest Service. Pp. 331-345.</p> <p>2 - Somewhat Relevant to Jackson WHMP</p> <p>DEMO study, pre-harvest baseline. Small terrestrial vertebrates numbered between 8 and 20 spp per stand based on pitfall captures.</p> <p>Spp richness of all terrestrial vertebrates grouped increased with increasing CWD volume. Spp richness of small mammals, insectivores and amphibians all correlated positively with CWD volume. No significant relationship between rodent richness and CWD.</p> <p>None of the vertebrate groups disclosed significant correlations between spp richness and snag volume.</p> <p>CWD volumes in this study were greater than 5x the current CWD Federal targets for sw OR. If stands are managed to Federal CWD targets (1994 USFS and BLM standards for habitat management for late-successional and old growth forest related species within the range of the northern spotted owl), full component of small terrestrial vertebrates typical of PNW forests will not be realized.</p>
151	<p>Manning, J.A., Edge, W.D. 2004. Small mammal survival and downed wood at multiple scales in managed forests. J. Mammal. 85(1):87-96.</p> <p>3 - Not Relevant to Jackson WHMP</p> <p>The authors sampled small mammals, understory vegetation and CWD at multiple scales (trap sites, 1-hectare patches and stands in 2 Douglas-fir forests in western Oregon. Study objectives: Do CWD or understory vegetation vary among or within forest patches or among forest stands? Does variation in small mammals survival coincide with the scale in which CWD or understory vary?</p> <p>Understory vegetation explain most of the variation within patches, but did not vary among patches or stands. Survival of deer mouse (<i>Peromyscus maniculatus</i>) and creeping vole (<i>Microtus oregoni</i>) varied within patches by differing among individual home ranges, and was most related to CWD volume and herb and grass cover. Survival of deer mice was explained by a polynomial function of CWD within individual home ranges, and peaked at 2.0 cu m per 0.01 ha. Survival of creeping voles was dependent on a negative log function of CWD within home ranges, and was highest in home ranges lacking CWD.</p>

	Results indicate these species may not be generalists, but rather specialists tied to specific amounts of particular habitat components within home ranges.
32	Marcot, B.G. 2004. Wood decay in healthy forests: the paradox and the promise. <i>Western Forester</i> 49(4):4-5. 3 - Not Relevant to Jackson WHMP
34	Marcot, B.G., Mellen, K., Livingston, S.A. 2002. The DecAID advisory model: wildlife component. In: Laudenslayer, R.F., J., Shea, P.J., Valentine, B.E., Weatherspon, C.P., Lisle, T.E., tech. coords. <i>Proc. Symp. On the ecology and management of dead wood in Western forests.</i> PSW-GTR-181. Berkeley, CA: USDA Forest Service, Pac. SW Res. Stn. 561-590. 1 - Very Relevant to Jackson WHMP See #66
66	Marcot, B.G., Mellen, K., Ohmann, J.L., Waddell, K.L., Willhite, E.A., Hostetler, B.B., Livingston, S.A., Ogden, C., Dreisbach, T. 2003. DecAID Decayed Wood Advisor. 1 - Very Relevant to Jackson WHMP Advisory tool to help managers evaluate effects of forest conditions and existing or proposed management activities on organisms that use snags and down wood. Advises on snag and CWD sizes and levels needed to help meet wildlife management objectives.
124	Marcot, B.G., R.S. Holthausen, J. Teply and W.D. Carrier. 1991. Old-Growth Inventories: Status, Definitions, and Visions for the Future In: Ruggiero, L. F. et al, editors. <i>Wildlife and Vegetation of Unmanaged Douglas-fir Forests.</i> USDA Forest Service, GTR-PNW-285. pp 47-60. 1 - Very Relevant to Jackson WHMP Provides definitions of Old-growth characteristics, cited by several authors as the basis for managing for PWP. Society of American Forests - 25+ snags/ha > 6m tall. 10+ snags/ha > 64cm dbh Old growth Definition Task Force - 10+ snags/ ha > 51 cm dbh and > 4.6m tall.
162	Martin, S.K., Barrett, R.H. 1991. Resting site selection by marten at Sagehen Creek, California. <i>Northw. Naturalist</i> 72:37-42. 2 - Somewhat Relevant to Jackson WHMP Study results from California: "Preserving large snags and logs for marten and leaving cull logs after timber harvest should benefit marten." "Average densities (no. per ha) in known marten habitat in our study were 46 snags, 66 stumps, and 39 logs." "The diameter of snags, stumps, and logs left for marten should be 80 cm or greater. Snags should be at least 4m tall, stump heights at least 80 cm and log lengths at least 10 m."
330	Mellen-McClean, K. 2007. Pers. Comm.: Phone conversation on behalf of USDA Forest Service. July 19, 2007. 1 - Very Relevant to Jackson WHMP Kim Mellen-McClean is the primary researcher responsible for integrating wildlife use data of dead wood into the DecAID advisory tool. The Forest Service often manages for "Natural Conditions" not wildlife species specifically. If the management goal is to manage for high quality wildlife habitat on all WHMP lands, then managing for dead wood at the 80% Tolerance Level across all acres would be appropriate (for

	<p>the Large Tree vegetation condition that is applicable to Lake Chaplain, the prescription would be for 36.4 snags/acre \geq 10" dbh including 14/acre $>$ 20" dbh.)</p> <p>The information shown in the wildlife data (as opposed to the plot inventory data) came from areas around nests, so providing dead wood at these levels across all acreages may not be necessary.</p>
37	<p>Mellen, K., Ager, A. 2002. A coarse wood dynamics model for the western Cascades. In: Laudenslayer, W.F., Jr., Shea, P.J., Valentine, B., Weatherspoon, C.P., Lisle, T.E., eds. Proc. Symp. On the ecology and Management of dead wood in western forests. Gen. Tech Rep. PSW-GTR 181. USDA Forest Service: Pac. SW Res. Stn. P. 503-516.</p> <p>2 - Somewhat Relevant to Jackson WHMP</p> <p>Model used to project the recruitment, snag fall rate, height loss and decay rate of snags and down wood to predict future amounts of dead wood habitat creation. Snags either fall whole or in parts, creating down logs. Snags also decay from a hard to soft condition. Logs decay more slowly than snags, and eventually disappear into the forest floor as duff. The model can track remnant snags and logs (i.e. those existing on site at the beginning of the assessment time) and new snags and logs created from green trees.</p>
36	<p>Mellen, K., Marcot, B.G., Ohmann, J.L., Waddell, K.L., Willhite, E.A., Hostetler, B.B., Livingston, S.A., Ogden, K. 2002. DecAID: A decaying wood advisory model for Oregon and Washington. PSW GTR-181. USDA Forest Service. 527-533.</p> <p>1 - Very Relevant to Jackson WHMP</p> <p>See #67</p>
67	<p>Mellen, K., Marcot, B.G., Ohmann, J.L., Waddell, K.L., Willhite, E.A., Livingston, S.A., Hostetler, B.B., Ogden, C., Dreisbach, T. 2006. DecAID - the decayed wood advisor for managing snags, partially dead trees, and down wood for biodiversity in forests of Washington and Oregon forests. Ver 2.0 US Forest Service, Pacific NW Region and Pacific NW Research Stn., Portland, OR.</p> <p>http://www.notes.fs.fed.us:81/pnw/DecAID/DecAID.nsf</p> <p>1 - Very Relevant to Jackson WHMP</p> <p>Computer program/management advisory tool.</p> <p>The DecAID database summarizes habitat associations of wildlife in terms of dead wood diameter and abundance. Can be used to determine either the species that would be provided for by retaining various densities and diameters of dead wood, or the levels of dead wood needed to provide habitat for species of interest.</p> <p>DEFINITIONS:</p> <p>Tolerance Level (TL) - an 80% tolerance level means that 80% of the population have a value for the given parameter that is between 0 and the value for the 80% TL. These are calculated based on 90% certainty levels. Example: an 80% TL of wildlife use of snag diameter means that 80% of all individuals observed uses snags less than or equal to some specified dbh, and 20% use snags greater than that dbh. The tolerance levels describe dead wood conditions across the total area within the vegetation condition.</p> <p>Large Tree - Single Story - Closed Canopy - QMD \geq 20" ; grass, shrub & seedling may occur in understory. Canopy cover is $>$70%; tree size is 20-29" dbh; single canopy stratum.</p> <p>Medium Tree - Single Story - Closed Canopy - QMD 10-19"; grass, shrub & seedling may occur in understory. Remnant trees can provide $<$10% canopy cover. Canopy cover is $>$70%; tree size is 15-19" dbh; single canopy stratum.</p> <p>FINDINGS - Snags & Cavity Nesters:</p> <p>Selection for - Selection for a given habitat attribute provides stronger evidence of a species'</p>

	<p>need than mere inventory data.</p> <p>Unharvested Westside forests provide a reasonable estimate of historical conditions.</p> <p>Advise against managing an entire landscape towards a particular tolerance level. Instead, distribution of habitat attribute should be guided by the distribution from unharvested plots. Areas should be managed within the complete range of dead wood values to provide for all species on the curve.</p> <p>The value of live and dead hardwood trees and partially dead trees of all species, should not be overlooked.</p> <p>If the objective is to manage for natural conditions rather than focusing on wildlife species, mimic distribution of unharvested acres (unharvested proportion of the landscape) in different snag density classes across the landscape. The percentages should be thought of as guidelines, since distributions largely reflect plot size and sample design. Balancing high, moderate and low densities of dead wood across a landscape may be desirable.</p> <p>Data are not available on the spatial distribution of dead wood within stands. Species often use clumps of snag & dead wood. Numbers and sizes of clumps are not indicated by this data. Areas between clumps should not be devoid of snags; a mix of clumps and more widely distributed snags should occur at the stand level.</p> <p>SPECIFIC RECOMMENDATIONS: Clustered and scattered snags receive equal use for nesting and foraging.</p> <p>Provide a variety of tree species, hardwoods and white pine are highly selected when available.</p> <p>Particularly tall trees and snags (up to 110ft) are selected for, as roost trees by some bat species, esp. those that protrude above the canopy.</p> <p>Retain all hollow trees, snags and logs. Cedar and hemlock are more susceptible to hollowing.</p> <p>Favor trees with fruiting fungal bodies, esp. of heart rot fungi, as well as forked tops, broken tops and brooms. These defective trees can substitute for some of the snags, counting towards density & dbh requirements.</p> <p>For 80% TL, manage for 36.4 snags/ac \geq 10" dbh, with 14/ac $>$ 20" dbh. The complete range of diameters and densities should be managed for to provide for all species utilizing snags.</p> <p>Snags as large as 79" dbh should be provided for PWP roost trees. For all other species, snags $>$ 63" dbh should be provided.</p> <p>These data will provide a CONSERVATIVE APPROACH to snag habitat management.</p> <p>Wildlife use data and inventory data from unharvested plots both support managing snags at the 80% TL .</p> <p>Several studies indicate that even higher densities of snags are justified on at least some of the landscape, (46.9/ac $>$ 10" dbh and 14-20/ac $>$ 19.7" dbh). Snag densities such as these occur on 6-10% of the unharvested landscape.</p> <p>The 80% TL for DBH of snags used by wildlife (nesting, roosting and foraging) ranges from 33 to 79" dbh. Most nest and roost snags are greater than 47" dbh. All roost trees found were $>$ 43" dbh.</p>
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	<p>Snags > 39.4" dbh comprise about 7% of all snags measured, and occur on 54% of the unharvested lands in this vegetation condition.</p> <p>The 80% TL for DENSITY of snags used by wildlife ranges from 19-36/acre $\geq 10"$ dbh, and 2-14/ac $\geq 20"$ dbh. For unmanaged stands aged 80 to 195 years, the 80% TL provides 46.9/ac $\geq 10"$ dbh and 13.9/ac $\geq 19.7"$ dbh.</p> <p>Based on tree availability, PWP on the Olympic Peninsula selected against hemlock and selected for Silver fir as nest trees and selected for cedar as roost trees.</p> <p>Half of the nests and roost were found in decadent live trees, even though they were much more rare than snags.</p> <p>Densities of dead top live trees around PWP nest and roost sites was higher than at random sites.</p> <p>DISTRIBUTION OF SNAGS:</p> <p>**40% of the unharvested area and 30% of the total area supports > 18.2 snags/ac $\geq 10"$ dbh.</p> <p>** 40% of the unharvested area and 29% of the total area supports > 8.1 snags/ac $\geq 19.7"$ dbh.</p> <p>Dwarf mistletoe is important for providing roosting and nesting structures for birds and small mammals. Hemlock is most susceptible, and therefore the most important for wildlife habitat. 14% of unharvested and 12% of harvested plots have some level of infection by mistletoe.</p> <p>Removing woody structure can have short-term benefits to planted seedling growth but longer-term adverse effects on overall forest productivity.</p> <p>Notes on CWD (see notes on snags, above, and add the following): These notes pertain to westside lowland conifer-hardwood forest, western Washington Cascades, Larger trees vegetation condition (QMD >50 cm (19.7 in.)). To provide longer lasting dead wood, consider that time from death of tree to falldown varies by cause of death. Trees killed by mammals, insects and suppression are most likely to remain standing as snags, while trees killed by windthrow and root disease are most likely to fall down soon after death. Western red cedar logs will decay more slowly than Douglas-fir or hemlock.</p> <p>CWD percent cover and diameter recommendations:</p> <p>80% TL: Provide undisturbed, high-density clumps of down wood of 5 to 19% cover (includes all decay classes). The 80% TL for unharvested inventory plots is 12% cover, but many species are associated with % cover of CWD above the 80% TL. Manage for a mix of sizes of CWD, averaging 30 to 50 cm (12 to 20in) in diameter for the stands. Minimum size for the inventory is 10 cm (4in.) Manage some pieces of CWD at least 60 to 80 cm (24 to 32 in) in diameter for Van Dyke's salamanders.</p> <p>Avoid disturbance of class 5 CWD as it is important for some species of wildlife and for site productivity. Manage for stand average percent cover of about 12% of class 1-4 CWD.</p> <p>Mean down wood lengths ranged from 6 m (20 ft) for roosting long-eared myotis to 20 m (66 ft) where Oregon slender salamander were present. All species except Van Dyke's salamander were represented by only one study. All but 2 studies looked at either salamander presence or nest use of down wood pieces. The other studies looked at foraging use of down wood by PWP, and roost use by long-eared myotis. Doyle (1990) found that the number of Townsend's chipmunk captures was significantly correlated with the total length of decayed logs. Hartwig</p>
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	(1999) found that PWP foraged on logs that were larger in diameter and length. Corkran et al (1997) found that an increase in log length increased the odds of OR slender salamander occupancy on a site.																																
64	<p>Ohmann, J.L., Waddell, K.L.. 2002. Regional patterns of dead wood in forested habitats of Oregon and Washington. In: Laudenslayer, W.F. et al. eds. Proceedings of the Symposium on the Ecology and Management of Dead Wood in Western Forests. US Forest Service PSW-GTR-181. pp. 535-560.</p> <p>1 - Very Relevant to Jackson WHMP</p> <p>Mike:</p> <p>Analysis of dead wood (snags & CWD) across 20 million hectares (over 16,000 field plots) of Federal and non federal lands in OR & WA, divided by the Cascade Crest.</p> <p>Dead wood abundance increased with successional age.</p> <p>SNAGS:</p> <p>Mean density of snags ≥ 25.4 cm dbh, all decay classes, ≥ 2 m tall, by forest type and successional stage:</p> <table> <tr> <td>West side conifer-hardwood</td><td>Early succession = 5.3/ha</td></tr> <tr> <td></td><td>Middle succession = 12.3/ha</td></tr> <tr> <td></td><td>Late succession = 14.6/ha</td></tr> <tr> <td></td><td>All stages = 10.2/ha</td></tr> <tr> <td>West side Conifer</td><td>Early succession = 5.2/ha</td></tr> <tr> <td></td><td>Middle succession = 21.4/ha</td></tr> <tr> <td></td><td>Late succession = 34.0/ha</td></tr> <tr> <td></td><td>All stages = 16.1/ha</td></tr> </table> <p>West side conifer-hardwood forests had 2nd most numerous population of large snags (behind montane mixed-conifer forest, due to slow deterioration of snags)</p> <p>Mean density of LARGE snags ≥ 50.0 cm dbh, all decay classes, ≥ 2 m tall, by forest type and successional stage:</p> <table> <tr> <td>West side conifer-hardwood</td><td>Early succession = 2.1/ha</td></tr> <tr> <td></td><td>Middle succession = 4.2/ha</td></tr> <tr> <td></td><td>Late succession = 7.8/ha</td></tr> <tr> <td></td><td>All stages = 3.7/ha</td></tr> <tr> <td>West side Conifer</td><td>Early succession = 2.1/ha</td></tr> <tr> <td></td><td>Middle succession = 7.5/ha</td></tr> <tr> <td></td><td>Late succession = 15.6/ha</td></tr> <tr> <td></td><td>All stages = 6.4/ha</td></tr> </table>	West side conifer-hardwood	Early succession = 5.3/ha		Middle succession = 12.3/ha		Late succession = 14.6/ha		All stages = 10.2/ha	West side Conifer	Early succession = 5.2/ha		Middle succession = 21.4/ha		Late succession = 34.0/ha		All stages = 16.1/ha	West side conifer-hardwood	Early succession = 2.1/ha		Middle succession = 4.2/ha		Late succession = 7.8/ha		All stages = 3.7/ha	West side Conifer	Early succession = 2.1/ha		Middle succession = 7.5/ha		Late succession = 15.6/ha		All stages = 6.4/ha
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294	<p>Pers. Comm: Buursma, Ed. 2007. Phone conversation on behalf of Mt Hood National Forests, Clackamas Ranger District. May 16, 2007.</p> <p>1 - Very Relevant to Jackson WHMP</p> <p>In riparian reserve areas adjacent to harvest units, 10 trees/acre were topped, 10/ac girdled, and some felled to thin out dense second growth.</p> <p>About 3 out of every 10 snags are placed in clumps.</p> <p>Have been inoculating for a few years, but have no results yet.</p> <p>Have been topping snags for about 20 years.</p>																																
14	<p>Public Utility District No. 1 of Snohomish County and City of Everett, Washington. 1988. Wildlife Habitat Management Plan, Henry M. Jackson Hydroelectric Project, 3 Vol., Paging various.</p> <p>1 - Very Relevant to Jackson WHMP</p>																																
263	Reutebuch, S.E., Haring, C.A., DeBell, D.S., Marshall, D.D., Curtis, R.O. 2002. Silvicultural Options for																																

	<p>Multipurpose management of west-side Pacific Northwest forests. In: Parker, S., Hummel, S.S., compilers. Beyond 2001: A silvicultural odyssey to sustaining terrestrial and aquatic ecosystems. Pro. 2001 Natl. Silvicultural Workshop, May 6-10, Hood River, OR. Gen. Tech. Rep. PNW-GTR-546. Pac. NW Res. Stn., Portland, OR. USDA Forest Service, pp. 38-46.</p> <p>2 - Somewhat Relevant to Jackson WHMP</p> <p>Describes long-term research study setup by Westside Silvicultural Options Team of the PNW research station (USFS). Authors point out that there are many new silvicultural approaches, but little research or operational experience that validate successful outcomes of new approaches to produce wildlife habitat, diversity, heterogeneity of stand structures, old growth features, etc. while still producing wood products. No young stands have been managed for an extended period under the proposed alternative methods. Most of the existing work with alternatives to even-age management in the douglas-fir region was done in old growth stands and has little relevance to management of young-growth stands.</p> <p>3 large-scale studies will focus on major stages of managed stands:</p> <ul style="list-style-type: none"> **early development (precommercial thinning) **midrotation (commercial thinning) **regeneration harvest <p>Objectives related to managing for wood production, wildlife habitat and other forest resource values.</p> <p>All 3 studies will measure response of overstory trees and understory plant species, and also CWD</p> <p>Young Stands:</p> <p>Experiments set up in Mt. St. Helens Nat'l Volcanic Monument, young, vigorous uniform Douglas-fir plantations, planted in mid-1980s. Treated in 1994-95. Remeasured 3 and 5 yrs later.</p> <p>Study goals:</p> <ol style="list-style-type: none"> 1. Test how silviculturally induced variation in tree spp composition and stand structure affect plant and animal populations. 2. Quantify the effects of different silvicultural regimes on tree and stand characteristics and production of forest products. <p>5 treatments for young stands:</p> <ol style="list-style-type: none"> 1. Control plots. Primarily Douglas-fir 680 tpa, one canopy layer, little understory veg. 2. Thinning to 50% of density with uniform tree spacing, and no alteration of spp composition. Possible future commercial thinning, retaining largest, most vigorous Douglas-fir in uniform spacing. 3. Uniform thinning as in 2., with evening spaced openings (40 x 40 ft). Supplemental plantings of red alder, western hemlock and western redcedar. Future commercial thinning to emphasize increasing tree species diversity rather than uniformity. 4. Variable density thinning with variable-size openings to increase structural heterogeneity. Stands evenly thinned as in 2., then openings of 30 x 30 ft, 40 x 40 ft., and 50 x 50 ft. created. No underplanting. Future commercial thinning emphasizing increasing heterogeneity and tree species diversity--only allow harvest of Doug-lar and expand or creating new openings. 5. Treatment as in 4., but interplant openings with red alder, western hemlock and western redcedar. 30 large tps fertilized--for future snag production. Future commercial thinning to accelerate development of multi-layered, uneven-aged mixed-species stands. <p>-----</p> <p>Midrotation stands:</p> <p>Westside Silvicultural Options and the Ecological Foundations of Biodiversity Teams from the Olympic Forestry Sciences Lab designed the Olympic Habitat Development Study of silvicultural options for closed-canopy midrotation stands on the Olympic Peninsula. Study</p>
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	<p>stands are 30- to 70-yo stands of Douglas-fir, western hemlock and Sitka spruce. Pretreatment baseline data on small mammal and amphibian populations, understory species, and CWD quantity collected from 1995 - 1998. Treatment of some blocks in 1997 - 99. Remaining blocks delayed. Some post-treatment surveys completed.</p> <p>Study Goals:</p> <ol style="list-style-type: none"> 1. Test efficacy of specific mgt. practices to accelerate late-successional stand structure and plant and animal communities. 2. Test if accelerating the development of late-successional structures in closed-canopy midrotation stands will increase habitat value for terrestrial amphibians and small mammals. 3. Develop and test operational prescriptions that allow wood production consistent with sustainable ecosystems. <p>Variable-density thinning: 10 % of the area in no-cut patches to protect existing snags and forest floor patches, 15% in small (65 ft x 65 ft) gaps, 75% lightly thinned from below (removal of 30% of basal area). CWD treatments.</p> <p>5 treatments for midrotation stands:</p> <ol style="list-style-type: none"> 1. Untreated control 2. VDT with scattered slash and logs. Additional trees felled to supplement CWD levels. 3. VDT with scattered slash and clumped logs. Additional trees felled to supplement CWD levels. 4. VDT with slash piles and clumped logs, and supplemental planting of trees in gaps. Additional trees felled for CWD. 5. VDT with scattered slash and no supplement CWD. <hr/> <p>Regeneration harvest methods: Silvicultural options for harvesting young-growth forests, in collaboration with DNR on Capitol Forest. First block harvest in 1998, replanted in 1999. Post-treatment song bird survey.</p> <p>Study goals:</p> <ol style="list-style-type: none"> 1. Evaluate biological, economic and visual effects of alternative timber harvest and management regimes for young-growth forests. 2. Provide demonstrations of contrasting silvicultural systems that are biologically feasible for managing young-growth forests. <p>Treatments for young-growth stands;</p> <ol style="list-style-type: none"> 1. Clearcut and manage similar to traditional even-aged standards, with PCT and CT as rel. stand densities exceed desired targets. 2. Retained overstory - Resembles shelterwood, but residual trees carried through next rotation. 15 evenly spaced tpa retained. 3. Small patch cutting - An even-aged system with small openings (1.5 to 5 ac.) created over 20% of the unit. May concurrently thin remainder of stand. Future thinning if densities exceed targets. 4. Group selection - An uneven-aged system with evenly-spaced openings (up to 1.5 ac.) created over 20% of the unit. May concurrently thin remainder of stand. Future thinning if densities exceed targets 5. Extended rotation with commercial thinning. Thin from below, removing 30% of basal area throughout stand. Future thinning if densities exceed targets. 6. Unthinned control <p>Regeneration in treatments 1-4 will be by planting in openings >0.1 ac. No planting in 5-6.</p>
70	Rose, C.L., Marcot, B.G., Mellen, T.K. and others. 2001. Decaying wood in Pacific Northwest

forest: concepts and tools for habitat management. In: Johnson, D.H., O'Neil, T.A. eds. Wildlife-habitat relationships in Oregon and Washington. Corvallis, OR: Oregon State University Press. Chapter 24.

1 - Very Relevant to Jackson WHMP

Mike's notes:

Since the publication of Thomas et al.³⁶⁹ and Brown,⁴⁸ new research has indicated that more snags and large down wood are needed to provide for the needs of fish, wildlife, and other ecosystem functions than was previously recommended by forest management guidelines in Washington and Oregon. For example, the density of cavity trees selected and used by cavity-nesters is higher than provided for in current management guidelines.^{53, 102} Reductions

Habitat suitability for cavity-users is influenced by the size (diameter and height), abundance, density, distribution, species, and decay characteristics of snags.³⁰⁷ In addition, the structural condition of surrounding vegetation determines foraging opportunities.⁴⁰²

Total snag densities were greatest at higher elevations: 15.1/ac (37.2/ha) in montane mixed-conifer forest and 14.6/ac (36.0/ha) in subalpine parks (Table 1). Snags were least dense in the drier wildlife habitat types on the eastside: 0.3/ac (0.8/ha) in western juniper woodland and 2.0/ac (5.0/ha) in eastside ponderosa pine (Table 1). Large snags were most abundant in montane mixed-conifer forest (3.8/ac; 9.6/ha) and in westside conifer-hardwood forest (2.2/ac; 5.5/ha), and least abundant in western juniper woodland (0.1/ac; 0.2/ha) and ponderosa pine (0.4/ac; 1.0/ha) (Table 1).

A large proportion of the plots contained no snags or down wood, and a very small proportion of the plots contained extremely large accumulations of dead wood. Mean values for these skewed distributions must be interpreted with caution. The distribution of snags for the conifer alliance of westside conifer-hardwood forest (Figure 11) illustrate this pattern. In this wildlife habitat type, 39 percent of the area sampled had no snags.

Several major lessons have been learned in the period 1979-1999 that have tested critical assumptions of these earlier management advisory models:

- . Calculations of numbers of snags required by woodpeckers based on assessing their biological potential. (that is, summing numbers of snags used per pair, accounting for unused snags, and extrapolating snag numbers based on population density) is a flawed technique. Empirical studies are suggesting that snag numbers in areas used and selected by some wildlife species are far higher than those calculated by this technique.²²⁶
- . Setting a goal of 40% of habitat capability for primary

	<p>excavators, mainly woodpeckers, 369 is likely to be insufficient for maintaining viable populations.</p> <ul style="list-style-type: none"> . Numbers and sizes (dbh) of snags used and selected by secondary cavity-nesters often exceed those of primary cavity excavators. . Clumping of snags and down wood may be a natural pattern, and clumps may be selected by some species, so that providing only even distributions may be insufficient to meet all species needs. . Other forms of decaying wood, including hollow trees, natural tree cavities, peeling bark, and dead parts of live trees, as well as fungi and mistletoe associated with wood decay, all provide resources for wildlife, and should be considered along with snags and down wood in management guidelines. <p>In addition, it may be both biologically and operationally beneficial to create and preserve snags within patches of uncut trees, rather than to distribute them uniformly across stands.</p> <p>Trees topped above two branch whorls survive and develop new tops. Continued diameter growth in these trees provide higher values as wildlife snags. Large crooks formed in these trees also provide platform nest sites and create future breaking points to form a tall snag. The greater longevity of these live-topped trees should reduce the need to cause intentional mortality in leave trees in the future.</p> <p>Topped trees rapidly develop cavities throughout the bole. Live-topped trees develop cavities ten years after topping, with cavities forming first near the upper bole. The creation of live trees with cavity habitat is highly desirable, as it allows cavity habitat to be maintained over longer periods.</p> <p>Big-leaf maple has relatively high survival and provides a high density of cavity sites.</p> <p>Notes on CWD:</p> <p>The volume of total and large down wood generally increases with forest development: large successional stages contained the largest concentration of both total and large down wood, although some young stands may inherit CWD and live trees from preceding stands. In westside forests, the volume of total and large down wood in the late stage usually was significantly different from the early and mid stages, but early and mid stages were usually not significantly different from one another. CWD has a longer lag time in forests than snags and is less likely to be disturbed by management activities.</p> <p>Estimates of mean total WD (>4.9 in large end, >6.6 ft long) volume in 3 successional stages of westside conifer-hardwood forest ranged from 2,169 to 3,233.8 cu ft/ac. Large WD (>19.7 in large end, >6.6 ft long) ranged from 1,408 to 2,469 cu ft/ac.</p> <p>Management tools and opportunities</p>
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	<p>Retain large snags, large decadent trees, and logs from previous rotation. To reduce safety and operational hazards, cluster snags in patches rather than wide dispersal, and create snags from green trees after harvest.</p> <p>Green tree retention (10-40%) of living trees, including dominants, through next rotation. Green tree retention on a harvest cycle of 120 yrs proposed as a method of provide habitat for late successional spp in only 40-50 yrs. The DEMO program offers information on wildlife and vegetation response to green tree retention.</p> <p>Variable density thinning. Also, aggregated or "patch" retention of small forest patches instead of dispersed retention, is suggested.</p> <p>Thinning and long rotations promote stand development and, thus, larger trees available for dead wood creation.</p>
135	<p>Spies, T.A., Franklin, J.F. 1988. Old growth and forest dynamics in the douglas-fir region of western Oregon and Washington. Nat. Areas. J. 8(3):190-201.</p> <p>2 - Somewhat Relevant to Jackson WHMP</p> <p>Provides interim definitions for old growth in the Douglas-fir and mixed conifer region of Washington, Oregon and northern California, based on minimal numbers and sizes of large live trees, canopy structure, snags and logs. For Douglas-fir on western hemlock sites (western hemloc, Pacific silver fir) stand characteristics are as follows:</p> <p>live trees: Two or more species with wide range of ages and sizes. Douglas-fir >8 per acre of trees >32 inches or >200 years old. Tolerant associates (western hemloc, western redcedar, Pacific silver fir, grand fir, or big-leaf maple) >12 per acre of trees >16 inches</p> <p>canopy: deep multi-layered canopy</p> <p>snags: conifer snags >7 per acre that are >20 inches in diameter and >15 ft. tall</p> <p>logs: Logs >15 tons per acre including 4 pieces per acre >24 inches in diameter and >50 ft. long</p>
178	<p>Spies, T.A., Franklin, J.R., Thomas, T.B. 1988. Coarse woody debris in Douglas-fir forests of western Oregon and Washington. Ecol. 69:1689-1702.</p> <p>3 - Not Relevant to Jackson WHMP</p>
116	<p>Stevens, V. 1997. The ecological role of coarse woody debris: an overview of the ecological importance of CWD in B.C. forests. Res. Br., BC Min. For., Victoria, BC. Work Pap. 30/1997.</p> <p>3 - Not Relevant to Jackson WHMP</p> <p>Good review of functions, wildlife associations, decay processes and research needs for CWD, but no management recommendations.</p> <p>Appendix 2 lists natural levels of CWD in BC forests, in cubic m/ha.</p>
223	<p>Stevenson, S.K., Keisker, D.G. 2002. Evaluating the effects of partial cutting on wildlife trees and coarse woody debris. In Gen. Tech. Rep. PSW-GTR-181. USDA Forest Service.</p> <p>2 - Somewhat Relevant to Jackson WHMP</p>
38	<p>Torgerson, R, Duncan, S. 2002. When the trees die. The World & I. 140-147.</p> <p>3 - Not Relevant to Jackson WHMP</p>
65	<p>US Forest Service. 1999. Dead and dying trees: essential for life in the forest. Science Findings 20. November 1999.</p> <p>1 - Very Relevant to Jackson WHMP</p>

	<p>Mike: SNAGS: To create a hollow cavity, the decay process must begin early in the life of a live tree. Entrances used by wildlife are typically between 30 and 80 feet off the ground. Recent studies show that an increase in the number of snags per acre is needed if snags providing roosting, nesting, foraging, denning, shelter and resting are to be provided. Current Forest Service e guidelines and standards are inadequate.</p>
195	<p>US Forest Service. 2000. Northern region snag management protocol. Snag Protocol Team. USDA Forest Service, Northern Region. 34 p. 3 - Not Relevant to Jackson WHMP From Forest Service Region 1, Northern Region, Idaho & Montana.</p>
31	<p>US Forest Service. 2006. If a tree falls in the woods, who will measure it? DecAID decayed wood advisor. Science Findings. PNW 83. See #36, 67</p>
30	<p>US Forest Service. 2004. Dead wood, living legacies: habitat for a host of fungi. Science Findings. PWN 66. 3 - Not Relevant to Jackson WHMP</p>
182	<p>Williams, M.S., Ducey, M.J., Gove, J.H. 2005. Assessing surface area of coarse woody debris with line intersect and perpendicular distance sampling. Can. J. For. Res. 35:949-960. 3 - Not Relevant to Jackson WHMP</p>
222	<p>Wilson, S.F., Craig, V. 2001. Footprint impacts of hydroelectric development on coarse woody debris; an assessment for Vancouver Island watersheds. Report prepared for BC Hydro Bridge-Coastal Fish and Wildlife Restoration Program. 27 pp. 2 - Somewhat Relevant to Jackson WHMP</p>
256	<p>Wilson, S.M., Carey, A.B. 2000. Legacy retention versus thinning; influences on small mammals. Northwest Science 74(2):131-145. 2 - Somewhat Relevant to Jackson WHMP Thinned areas had 1.5x the individual mammals and 1.7x the mammal biomass versus forests that were harvested but retained legacies from the previous forest (live trees, snags, cwd).</p> <p>Thinned stands showed a greater abundance, biomass and diversity of small mammals compared to legacy stands, but neither type of management supported the complete small-mammal community found in old growth forests.</p> <p>***authors suggest that combining thinning and legacy retention could provide more benefits than either of the individual strategies tested here.</p>

Deer Forage

59	<p>B.C. Ministry of Forests. 1996.Coastal Black-tailed deer study. McNay, R. S. 1996.Coastal Black-tailed deer study. B.C. Ministry of Forests, Research Branch, Victoria, B.C. Paging various.</p> <p>1 - Very Relevant to Jackson WHMP</p> <p>A series of 5 pamphlets summarizing research by Integrated Wildlife-Intensive Forestry Research Program (IWIFR). Research team tracked 89 radio-collared black-tailed deer for 9 yrs on coastal Vancouver Island sites. Habitat was primarily river valleys with young (6-45 yo) forests in valley bottoms, mostly deforested mid-slopes, and old forests in higher elevations and headwaters.</p> <p>1. Decoding deer movement patterns</p> <p>Young deer rarely disperse to new ranges.</p> <p>3 behavior types distinguished: resident deer who always stayed close to natal ranges, regular migrators who always moved from higher elevation summer range to lower-elevation winter range, and irregular migrators. Resident deer stayed in their low-elevation ranges and habitats all year. Migrators had mid- to high-elevation natal ranges and did not move more than 5.5 km from summer to winter range.. Irregular migrators (from mid-elevations) only used alternate ranges when snowpack forced them to move. Rarely moved more than 3 km, however.</p> <p>Black-tailed deer move little when compared to other large mammals. Radio-collared deer were rarely found more than 1 km from their last location. Rare to find deer more than 250 m from forested shelter. Home range sized varied from 1.9 km² for residents to 1.7 km² for migrators.</p> <p>2. Clarifying habitat use</p> <p>Deer primarily used young (6-45 y.o.) forests. Less old forest was used in summer, while young forests and open habitat were used more. Deer in the study habitually used the same sites and their preferred habitats were often not ideal. Low-elevation, resident deer had small ranges that normally included adequate forage in young and open forest..</p> <p>3.How black-tailed deer react to logging in their winter habitat</p> <p>Old forests, especially at low elevations, provide preferred habitat during severe winter conditions. Use of low-elevation forest, although steady prior to logging disturbance, reduced considerably after logging even when this same type was available close by. Loyalty to the actual range, rather than a preference for a particular type of winter habitat, dominates initial responses by deer to large, striking changes in habitat condition.</p> <p>Good winter range has 4 micro-habitat: open forage production forest, openings, thickets</p> <p>Management of young forests to improve suitability as winter habitat for deer may only benefit deer in the direct vicinity, at least initially. May not see an immediate response when habitats are upgraded. Deer take some time to learn about improvements due to strong loyalty to specific sites.</p> <p>4. Habitat and predator concerns</p> <p>Wolves and cougars accounted for 61% of all deaths; cougar more important predator. The more territorial cougars established activity centers and killed deer in isolated stands of old growth forest. Most of these stands were winter habitat for deer. Resident low-elevation deer most susceptible to predation. April through July predation was highest.</p> <p>Forest harvest indirectly creates easy access for predators and isolates winter ranges. Early seral forests created by clearcuts offer abundant high-quality forage. Logging road systems also provide easy access to deer by wolves, cougars and humans; rsulting mortality risk to adult deer probably outweighs any potential benefit from improved habitat quality. Migratory</p>
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	<p>deer escape some predation by leaving lowland winter ranges during March, before predators became most active. Also, there is less road access in steeper terrain at higher-elevations, which reduces risk of predation.</p> <p>Logging isolates old growth winter ranges, concentrating deer in specific areas and focusing predator attention toward them. Low-elevation deer populations on Vancouver Island may have survival rates that are too low to sustain populations long-term.</p> <p>Authors recommend blocks of older intact forests be set aside to help rebuild deer populations.</p> <p>5. Habitat assessment and planning</p> <p>Important characteristics of suitable winter habitat:</p> <ul style="list-style-type: none"> *elevations <900 m *slopes 30-80% *southern aspect *tall, large-crowned conifers (65-70% crown closure) or *cedar-hemlock thickets *tall shrub understory *arboreal lichens <p>Suitable summer habitat:</p> <ul style="list-style-type: none"> *coolest aspects and elevations *moist areas with abundant herbs <p>A patchy forest with small openings usually provides better forage than dense forest with closed canopy. Food quality is determined by soil moisture and canopy closure. Moist to dry sites are best, very wet sites are poorest; older clearcuts (10 yrs) are best and old stands of second growth (80 yr) are poorest.</p> <p>Cover quality is determined by canopy closure: old stands of second growth and old growth are best; young clearcuts are poorest.</p> <p>High quality food and cover should occur together or be less than 500 m apart.</p> <p>Aspect and elevation modify deer habitat quality: south-facing slopes below 900 m are best; north-facing slopes and land above 900 m are poorest.</p>
329	<p>Brown, E. R., tech. ed. 1985. Management of Wildlife and fish habitats in forests of western Oregon and Washington. U.S. Forest Service ubl. No. \$6-F&WL - 192-1985. Portland, OR.</p> <p>1 - Very Relevant to Jackson WHMP</p> <p>Chapters in this document provide the basis for WHMP management techniques dealing with timber harvest, silviculture, deer forage, snag and coarse woody debris management.</p>
282	<p>Kerns, B.K., Alexander, S.J., Bailey, J.D. 2004. Huckleberry abundance, stand conditions, and use in western Oregon: evaluating the role of forest management. Econ. Botany 58(4):668-678.</p> <p>Analysis of data from old growth, young thinned, young unthinned Douglas-fir stands in western OR. All young stands 50 - 120 yrs old, with operational thinnings 10 - 25 yrs before this study. Old growth stands >200 yrs old.</p> <p><i>Vaccinium ovatum</i>, <i>V. parvifolium</i>, <i>V. membranaceum</i> studied. Results variable. Site history and conditions, such as substrate availability, apparently very important.</p> <p><i>Ovatum</i> associated with old growth and unthinned stands; stand thinning may not increase frequency or density. Slow-growing, shade tolerant sp. That lacks rhizomatous growth and might not be able to spread following stand thinning.</p>

	<p>Parviolium significantly more dense in young thinned stands than in young unthinned stands. Density also related to intensity of thinning.</p> <p>Membranaceum associated with old growth stands, but berry production tends to decline in closed-canopy forests.</p>
60	<p>Nyberg, J.B., Janz, D.E., eds. 1990. Deer and elk habitats in coastal forests of southern British Columbia. Res. Branch, BC Min.For., Victoria, BC. Spec. Rep. Serv. No.5.</p> <p>3 - Not Relevant to Jackson WHMP</p>
327	<p>Nyberg, J.B., McNay, R.S., Kirchhoff, M.D., Forbes, R.D., Bunnell, F.L., Richardson, E.L. 1989. Integrated management of timber and deer: coastal forests of British Columbia and Alaska. Gen. Tech. Rep. PNW-GTR-226. USDA Forest Service. Pac. NW Res. Stn. 65pp.</p>
326	<p>Nyberg, J.B., Bunnell, F.L., Janz, D.W., Ellis, R.M. 1986. Managing young forests as black-tailed deer winter ranges. BC Min.Forests. Land management report no. 37.</p>
14	<p>Public Utility District No. 1 of Snohomish County and City of Everett, Washington. 1988. Wildlife Habitat Management Plan, Henry M. Jackson Hydroelectric Project, 3 Vol., Paging various.</p> <p>1 - Very Relevant to Jackson WHMP</p>
109	<p>Wender, B.W., C. A. Harrington and J.C. Tappeiner II. Flower and Fruit Production of Understory Shrubs in Western WA & OR. NW Sci. 78:124-140.</p> <p>1 - Very Relevant to Jackson WHMP</p> <p>This study only considered a gap to be such when the ratio of gap width to canopy height was 1.0 or greater.</p> <p>Flowering was not observed on vine maple <10 years old (y/o), but was seen on stems up to 64 y/o.</p> <p>Hazelnut and huckleberry also flowered at ages > 20 y/o.</p> <p>Heavily flowering shrubs were more common in gaps than under intact canopies.</p> <p>Flower production of evergreen huckleberry (<i>V. ovatum</i>) increased as the overstory of conifers increased, but decreased as the crowns of overstory trees overlapped.</p> <p>Intensity of commercial thinning was strongly correlated to production outcome for Oregon grape, ocean spray, red huckleberry, and was strongest for salal.</p> <p>Moderate thinnings, followed by heavy, then light thinning treatment were found to have the greatest impact on the probability of shrub flowering.</p> <p>Red huckleberry did not respond differently to varying levels of thinning.</p> <p>Plant size and age is more important in determining the likelihood of flowering for common understory shrubs than overstory density.</p> <p>The resources available also impact flower/fruit production by influencing the size of the plant, thus, canopy gaps should increase the amount of resources available to the plants and should in turn lead to increased flower/fruit production.</p> <p>Woody perennials have the ability to store resources for long periods of time, and therefore gap-induced plant growth may be hard to predict.</p> <p>Responses to gap creation or thinning may be delayed if conditions during the growing season</p>

	<p>are unfavorable (i.e. precipitation).</p> <p>Older legacy shrubs, or pockets thereof, may needed to be protected within a stand to ensure that large individuals are maintained into the next forest generation.</p>
259	<p>Witmer, G.W. et al. 1985. Deer and elk. In Brown, E.R., ed. Management of wildlife and fish habitats in forests of western Oregon and Washington. Pub. No. R6-F&WL-192-1985.Pac. NW Region, USDA Forest Service. Portland, OR, pp.231-258.</p> <p>1 - Very Relevant to Jackson WHMP</p> <p>Review/advisory article, offering management advice on a number of topics:</p> <ul style="list-style-type: none"> *Road location and design *Road management *Scheduling of timber harvest *Design and layout of harvest units *Debris management *Herbicide application *Precommercial thinning *Commercial thinning - thin to 60% crown cover or less for forage; maintain 70% crown cover for thermal cover. *Seeding, planting and fertilization - after harvest seed palatable forage *Forage area maintenance - maintain the area permanently in an early successional vegetative stage; and plant and fertilize preferred deer forage *Management of optimal cover
58	<p>WSU Coop. Extension. 1998. Managing deer on small woodlands. Woodland Fish and Wildlife. WSU Cooper. Extension. MISC0189 Rev. July 1998.</p> <p>1 - Very Relevant to Jackson WHMP</p> <p>Preferred Food Plants of black-tailed deer:</p> <p>Salmonberry, snow brus; new growth of: Douglas-fir, bitterbrush, willow, trailing blackberry, ceanothus, red huckleberry, vine maple, western red cedar, salal; forbs and legumes: alfalfa, clover, deer vetch, pearly everlasting, fireweed, vetch, deer fern, cats ear, balsam root; grasses and others: bluegrass, wheat, oats, lichens, mushrooms.</p> <p>Percent of area in cover: 40 -60</p> <p>Ratio of thermal to hiding cover: 50:50</p> <p>Forage: 50-100% herbaceous vegetation and/or shrubs less than 7 ft tall One-acre patches of forage, less than 600 ft from cover.</p> <p>Hiding cover: capable of screening 90% of a standing adult deer. 1 - 5 ac. patches</p> <p>Thermal cover: evergreen forest stand at least 40 ft tall, crown closure of at least 50-70%, smaller than 5 ac patches, large (21" diameter) trees preferable.</p>

Nest Structures

147	<p>Davis, J.B., R.M. Kaminski and S.E. Stephens. 1998. Wood Duck Eggshell Membranes Predict Duckling Numbers. Wildl. Soc. Bul. 26:299-301.</p> <p>2 - Somewhat Relevant to Jackson WHMP</p> <p>During nest box checks, membranes counted ≤ 5 days post-hatch provided an accurate estimate of number of ducklings; add 1 to this count to derive the most accurate count of hatchlings.</p>
144	<p>Hepp, G. R. and R. A. Kenamer. 1992. Characteristics and Consequences of Nest-Site Fidelity in Wood Ducks. Auk 109:812-818.</p> <p>2 - Somewhat Relevant to Jackson WHMP</p> <p>Individual cavity-nesting ducks that are successful are more likely to return to the same nest site than those that are unsuccessful.</p> <p>Those females that used the same box in subsequent years also began nesting earlier (13 days) and had larger clutches than those that returned to the same wetland, but chose a different box than the prior year.</p> <p>Buffleheads tended to show greater nest site fidelity than wood ducks or common Goldeneyes.</p>
14	<p>Public Utility District No. 1 of Snohomish County and City of Everett, Washington. 1988. Wildlife Habitat Management Plan, Henry M. Jackson Hydroelectric Project, 3 Vol., Paging various.</p> <p>1 - Very Relevant to Jackson WHMP</p>
145	<p>Semel, B. And P. W. Sherman. 1995. Alternative Placement Strategies for Wood Duck Nest Boxes. Wildl. Soc. Bul. 23:463-471.</p> <p>2 - Somewhat Relevant to Jackson WHMP</p> <p>Conducted in Illinois, but some strategies are still applicable.</p> <p>Visible duplex boxes (traditional placement) were parasitized more often than hidden/dispersed boxes (non-traditional placement).</p> <p>Clutches in traditional boxes were less likely to hatch than those in non-traditional boxes (45% vs. 64%), resulting from brood parasitism.</p> <p>Ultimately, the same number of fledglings were produced from each box (9.0 in traditional vs. 9.2 in non-traditional), but a much greater number of unfledged ducklings resulted from the traditionally placed boxes (10.9 vs. 4.4, respectively).</p> <p>Among the findings:</p> <ul style="list-style-type: none"> **Nest box placement and frequency of brood parasitism were directly related. ** scarcity of unused boxes does not determine rate of parasitism. **full reproductive potential is more likely to be reached if boxes are placed inconspicuously.
148	<p>Semel, B. and P. W. Sherman. 1992. Use of Clutch Size to Infer Brood Parasitism in Wood Ducks. JWM 56:495-499.</p> <p>2 - Somewhat Relevant to Jackson WHMP</p> <p>Parasitism is inferred from the following 4 criteria:</p> <ul style="list-style-type: none"> ** addition of ≥ 2 eggs in a 24 hour period; ** addition of eggs after incubation has begun; ** eggs that differ in color or shape from the remainder of the clutch; ** "supernormal" clutch size.

	Parasitism rates inferred from clutch size alone are unreliable.
156	<p>Stephens, S.E., R. M. Kaminski, B. D. Leopold & P. D. Gerard. 1998. Reproduction of Wood Ducks in Large and Small Nest Boxes. Wildl. Soc. Bul. 26:159-167.</p> <p>3 - Not Relevant to Jackson WHMP</p> <p>Study conducted in Mississippi.</p>
146	<p>Utsey, F. M. And G. R. Hepp. 1997. Frequency of Nest Box Maintenance: Effects on Wood Duck Nesting in South Carolina. JWM 61:801-807.</p> <p>2 - Somewhat Relevant to Jackson WHMP</p> <p>Study was conducted in S. Carolina, but some results are applicable here:</p> <p>To maximize nest box use and duckling production, nesting materials should be removed after peak of nesting season and again immediately after the breeding season. This will also allow better estimates of nest box use, success and productivity.</p>
157	<p>Zicus, M.C. 1990. Nesting Biology of Hooded Mergansers Using Nest Boxes. JWM 54: 637-643.</p> <p>3 - Not Relevant to Jackson WHMP</p> <p>Study conducted in Minnesota</p>

Old Growth

39	<p>Andrews, L.S., Perkins, J.P., Poage, N.J., Tappeiner II, J.C. 2005. Silvicultural approaches to develop northern spotted owl nesting sites, Central Coast Ranges, Oregon. <i>West. J. Appl. Forestry</i> 20(1):13-27. Review articles and computer simulation that uses tree growth model ORGANON for central coast range region. Explores a range of 32 management scenarios for Douglas-fir stands 50 y.o. (170-247 tpa) and estimated which scenarios promoted the development of forest patches that emulate the species mix and diameter distributions of known spotted owl nest sites.</p> <p>It was difficult to alter the development trajectory of stands first managed at 50 yrs. Management earlier in the development of natural stands would have promoted the growth of large trees with deep crowns, reduced overstory density to levels consistent with those of older forests, promote understory development including shrub layers, and lead to greater differentiation in diameter distributions in a shorter time frame.</p> <p>Without silvicultural action (or natural disturbances), stands did not develop nesting habitat features within the 160 year simulation.</p> <p>In most simulation trials, commercial thinning from below at 50 yrs. Heavy thinning retained 30-45 tpa, light thinning retained 126-149 tpa. Retained hardwoods, shade-tolerant conifers and large-diameter Douglas-fir. At 80 yrs simulated thinning across a range of densities while thinning from above, below, or proportionally. At 120 yrs, modeled a uniform proportional thinning.</p> <p>Heavy to moderate thinning with extended rotations appeared to promote the development of spotted owl nest habitat while shortening the duration of the least diverse (for wildlife) stage of stand development. Stands also required production of snags and coarse woody debris under these scenarios.</p> <p>A number of simulation pathways were discovered leading to suitable nest habitat features, suggesting that stand management can follow multiple routes from dense young stands to structures similar to old growth forests.</p> <p>Management suggestions:</p> <ul style="list-style-type: none"> **Early commercial thinning, <50y.o. **Low overstory density promotes deep canopies, large-diameter branches, establishment of understory trees. Many naturally regen old-growth stands in the Coast Ranges appear to have initially developed at low stocking densities (aprox. 50 tpa) with gradual and ongoing ingrowth, probably owing to periodic and relatively intense wildfire events. Heavy thinning in young stands could be used to promote structures that emulate old-growth stands. **Multiple entries that thin both canopy layers may be required to optimize understory development when light or moderate thinning is applied, to avoid crown closure. **Short-term drawbacks to heavy thinning: As surface drying increases, development of brush fields or invasion by exotic plants may happen. **Heavy thinning of dense, developing young stands increases the potential for windthrow. If windthrow is expected, incorporate it into silvicultural planning. Select leave trees with the lowest H/D ratios. Several entries can be used to thin stands in stages to reduce windthrow damage. Low H/D ratios can be promoted through maintaining low initial stocking densities and/or by early stand thinning. **Variable-density thinning for structural heterogeneity in which intermediate-canopy trees can be released and regeneration, including underplantings, is encouraged. VDT emulates suppression mortality (light thinning), fine-scale disturbance (heavy thinning), and coarse-scale disturbance (patch cutting) within stands. **Culture trees in young low-density stands with the potential for legacy structures: trees with the lowest H/D ratios, multiple large limbs and potential for epicormic branching. Simulations
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	<p>predict that heaving thinning at age class 50 yrs may develop these legacy surrogates more quickly.</p>
275	<p>Bailey, J.D., Mayrsohn, C., Doescher, P.S., St. Pierre, El., Tappeiner, J.C. 1998. Understory vegetation in old and young Douglas-fir forests of western Oregon. <i>For. Ecol. And Manage.</i> 112:289-302.</p> <p>3 - Not Relevant to Jackson WHMP</p> <p>Field study of thinned and unthinned Douglas-fir stands in western OR. Stands had regenerated naturally after timber harvest, 40 - 70 yrs before thinning. Commercial thinning had occurred 10-24 yrs previously, with 8-60% of volume removed from below with intent to homegenize tree spacing. There were also undisturbed old-growth Douglas-fir reference sites.</p> <p>Total herb cover greater in thinned (25% cover) than unthinned (13%) or old-growth stands (15%). Species richness greater in thinned (137) than in unthinned (114) and old-growth (91). Part of increased richness caused by exotic spp in thinned stands, but these also had move native grass and nitrogen-fixing spp.</p> <p>Ordination of herbaceous community data showed there were much stronger differences among sites than among stand-types; This lack of difference among stand-types demonstrates the resiliency of herbaceous communities to disturbance associated with past and current forest management.</p>
290	<p>Bull, E.L., J.J. Akenson, B.J. Betts and T.R. Torgersen 1995. The Interdependence of Wildlife and Old-Growth Forests In: Bradford, P., T. Manning and B. l'Anson eds. <i>Wildlife Tree/ Stand-Level Biodiversity Workshop Proceedings</i>. Victoria, B.C. October 1995. 71-76.</p> <p>1 - Very Relevant to Jackson WHMP</p> <p>Mistletoe brooms are important nest structures for Great Gray and Great Horned Owls, as well as American Marten.</p> <p>Pileateds excavate new nests each year, and typically roost in hollow trees.</p> <p>The density of large green trees, canopy height, number of canopy layers and density of hard snags were all positively associated with woodpecker abundance.</p> <p>Vaux's swifts are known to be dependent on large diameter, hollow trees for nesting and roosting.</p> <p>Black bears commonly use hollow trees for denning. These trees averaged 114cm dbh (range 91-160cm) and 19m tall (range 8-30m). Trees with top entries are most commonly used by young bears and females, because they are more secure form predators.</p> <p>Martens regularly use large-diameter snags, logs and live trees as rest sites. 36% of rest sites were in platforms, usually resulting from mistletoe.</p> <p>Cavities made up 23% of rest sites, and hollow logs accounted for 10%.</p> <p>Bat roosts were usually found in snags (67% of roosts).</p> <p>The average dbh was 68 cm and height was 22m. The actual roost site was typically high in the tree, averaging 12m.</p>
136	<p>Bull, E.L., Torgersen, T.R., Blumton, A.K., McKenzie, C.M., Wyland, D.S. 1995. Treatment of an old growth stand and its effects on birds, ants, and large woody debris: A case study. <i>Gen. Tech. Rep. PNW-GTR-353</i>. Portland, OR: USDA Forest Service, Pac. NW. Res. Stn. 12 p.</p> <p>3 - Not Relevant to Jackson WHMP</p> <p>Research conducted in mixed-conifer stands in northeastern Oregon. Purpose of the study was to determine if an old-structure stand with high mortality due to spruce budworm could be altered to accelerate regeneration and reduce fuel loads but still maintain its function as old</p>

	<p>growth for selected bird species.</p> <p>Small-diameter (<15 in dbh) and dead trees were removed. Downed wood <15 in dbh was removed. All live trees of any size and all dead trees >15 in dbh were retained.</p> <p>Vaux's swifts and pileated woodpeckers continued to use the stand after harvest for nesting and roosting. The number of logs >15 in cbh increased, the number of logs with ants increased, but the percentage of logs with ants decreased. The percentage of logs with ants decreased precipitously during the study period. Pileated foraging on logs decreased in the treated stand.</p> <p>Results include only 1 year of data, and can't be used to make definitive recommendations.</p>
50	<p>Busing, R.T., Garman, S.L. 2002. Promoting old-growth characteristics and long-term wood production in Douglas-fir forests. <i>For. Ecol. And Manage.</i> 160:161-175.</p> <p>3 - Not Relevant to Jackson WHMP</p>
202	<p>Carey, A.B. 1995. Sciurids in Pacific Northwest managed and old-growth forests. <i>Ecol. Appl.</i> 5(3):648-661.</p> <p>3 - Not Relevant to Jackson WHMP</p>
52	<p>Carey, A.B., Johnson, M.L.. 1995. Small mammals in managed, naturally young, and old-growth forests. <i>Ecol. Applic.</i> 5(2):336-352.</p> <p>Compared small mammal communities in natural old-growth stands to managed even-aged and uneven-aged stands in Olympic Peninsula. While small mammal abundance and productivity for most species were greatest in natural old-growth, all spp abundance in managed stands as well. Abundance of small mammals in uneven-aged managed stands tended to be intermediate between natural old-growth and young even-aged stands.</p> <p>CWD and understory shrub layer key variables affecting small mammal abundance. Could be maintained or enhanced by partial cutting.</p>
278	<p>Carey, A.B., Wilson, T.M., Maguire, C.C., Biswell, B.L. 1997. Dens of northern flying squirrels in the Pacific Northwest. <i>J. Wildl. Manage.</i> 62(3):684-699.</p> <p>2 - Somewhat Relevant to Jackson WHMP</p>
253	<p>Christy, R.E., West, S.D. 1993. Biology of bats in Douglas-fir forests. <i>Gen. Tech. Rep. PNW-GTR-308.</i> Pac. NW Res. Stn. USDA Forest Service. 28 p.</p> <p>3 - Not Relevant to Jackson WHMP</p>
160	<p>Corn, J.G., Raphael, M.G. 1992. Habitat characteristics of marten subnivean access sites. <i>J. Wildl. Manage.</i> 56:442-448.</p> <p>3 - Not Relevant to Jackson WHMP</p> <p>Describes the importance of snags, stumps and logs in providing denning habitat in the central Rocky Mountains.</p>
21	<p>DNR. 1997. Final Habitat Conservation Plan. Washington Department of Natural Resources, Olympia, WA. Paging various.</p> <p>3 - Not Relevant to Jackson WHMP</p>
199	<p>Feller, M.C. 2003. Coarse woody debris in the old-growth forests of British Columbia. <i>Environ. Rev.</i> 11(s1):S135-s157.</p> <p>Synthesis of literature and data collected by the author on CWD in old-growth forests of British Columbia.</p> <p>3 - Not Relevant to Jackson WHMP</p>

79	Franklin, J., Spies, T.A., Van Pelt, R. (and others). 2002. Disturbances and structural development of natural forest ecosystems with silvicultural implications, using Douglas-fir forests as an example. <i>Forest Ecol. And Manage.</i> 155:399-423.
18	<p>Franklin, J.F., Berg, D.R., Carey, A.B., Hardt, R.A. 2006. Old-growth conifer forests in Restoring the Pacific Northwest. Dean Apostol & Marcia Sinclair, eds., Society for Ecological Restoration International. Island Press: Washington DC. Pp. 97-121.</p> <p>1 - Very Relevant to Jackson WHMP</p> <p>"How can younger forests be restored through active management to a state that provides similar functions and services as natural old growth?"</p> <p>Recommends: Develop a landscape-level plan. Not all younger forest stands need to be treated--consider them as part of a larger mosaic of future stand conditions. Emulate a reference old growth stand in the same area, consider variable density thinning, preserve old growth legacies (snags, CWD, decadent live trees), identify the role of shade-tolerant conifers and hardwoods in the desired future stand condition.</p>
46	<p>Gray, A.N. 2003. Monitoring stand structure in mature coastal Douglas--fir forest: effect of plot size. <i>For. Ecol. and Manage.</i> 175:1-16.</p> <p>3 - Not Relevant to Jackson WHMP</p>
25	<p>Gray, A.N., Spies, T.A. 1996. Gap size, within-gap position and canopy structure effects on conifer seedling establishment. <i>J.Ecology</i> 84:635-645.</p> <p>1 - Very Relevant to Jackson WHMP</p> <p>Portions of large gaps with direct exposure to the sun had relatively low seedling establishment, particularly for Hemlock. All species were most abundant in the shaded portions of gaps.</p> <p>An increase in gap size corresponded to an increase in seedling size, being the greatest at gap centers.</p> <p>Douglas fir seedling growth was relatively low except in the largest gaps. Hemlock growth increased dramatically with gap size, and silver fir responded the least to gap size.</p> <p>Created gaps may help to accelerate the development of multiple canopy layers.</p> <p>Seedling density appears better related to gap age than to gap size.</p> <p>Both Hemlock and Silver fir can survive for many decades with little growth in shaded forests, and resume growth following a disturbance and concomitant increase in light levels.</p> <p>Contrary to common opinion, Douglas fir can germinate in shade or become established on intact forest floor.</p>
26	<p>Gray, A.N., Spies, T.A. 1997. Microsite controls on tree seedling establishment in conifer forest canopy gaps. <i>Ecology</i> 78(8):2458-2473.</p> <p>1 - Very Relevant to Jackson WHMP</p> <p>Species composition within gaps is likely determined by more than size and shape of the gap; fine scale environmental factors may also be important.</p> <p>Gap sizes were determined by gap diameter:tree height ratios, and were classified as 0.2, 0.4, 0.6 & 1.0</p> <p>Douglas-fir reproduces best on mineral soil in high-light conditions. Hemlock is shade tolerant, but appears to be so sensitive to competition from other understory vegetation while in the seedling stage that successful regeneration is usually limited to growing on decaying Douglas-fir logs.</p> <p>Silver fir is also shade tolerant, but is sensitive to both overstory and understory canopy</p>

	<p>density.</p> <p>*** Many gaps were found to be devoid of tree saplings more than 50 years after gap formation.</p> <p>For seedling establishment, gap size was marginally significant.</p> <p>Silver fir and Hemlock seedling establishment was greater in the 0.2 and 0.4 gaps than in controls and 1.0 gaps.</p> <p>Hemlock establishment in the 1.0 gaps were significantly lower than the other species.</p> <p>Seedling size increased with gap size.</p> <p>Particularly for silver fir, seedling establishment in the 1.0 gaps was greatest in 90% shade.</p> <p>Seedling survival for both Douglas-fir and hemlock was highest on decayed wood.</p> <p>Douglas fir tended to survive best in shady portions of the sunniest gap area (i.e. north edge) and in the more open portions of the smaller, darker gaps (i.e. south edge).</p> <p>The advantage that hemlock incurs from growing on decaying wood appears to decrease with gap size.</p>
267	<p>Hansen, A.J., McComb, W.C., Vega, R., Raphael, M.G., Hunter, M. 1995. Bird habitat relationships in natural and managed forests in the west Cascades of Oregon. <i>Ecol. Appl.</i> 5(3):555-569.</p> <p>3 - Not Relevant to Jackson WHMP</p> <p>Bird abundance data from several studies.</p> <p>Most forest birds can be placed in 4 guilds in terms of overstory tree canopy use:</p> <p>**open canopy spp (dark-eyed junco, american robin)</p> <p>**open canopy with dispersed large trees (MacGillivray's warbler, Hammond's flycatcher, western tanager)</p> <p>**structurally complex closed-canopy (brown creeper, chestnut-backed chickadee, winter wren)</p> <p>**structurally simple closed-canopy (golden-crowned kinglet, Swainson's thrush)</p>
129	<p>Hansen, A.J., Spies, T.A., Swanson, F.J., Ohmann, J.L. 1991. Conserving biodiversity of managed forests. <i>Bioscience</i> 41(6):382-392.</p> <p>2 - Somewhat Relevant to Jackson WHMP</p> <p>Natural disturbance in unmanaged forests maintains structural complexity within stands, and this complexity promotes plant and animal diversity. This paper has a good discussion of the role natural disturbance and forest succession, including some data on snag and cwd densities in unmanaged forests.</p> <p>Recommendations for managed forests with biodiversity goals:</p> <p>Retain structural legacy from the preharvest stand, e.g. large trees in cutting units.</p> <p>Extend rotation ages.</p> <p>Produce new large trees, snags and CWD over the course of forest rotation.</p> <p>Preserve herb/shrub stage.</p>
166	<p>Hargis, C.D., McCullough, D.R. 1984. Winter diet and habitat selection of marten in Yosemite National Park. <i>J. Wildl. Manage.</i> 48:140-146.</p> <p>2 - Somewhat Relevant to Jackson WHMP</p> <p>California study results</p> <p>Recommendation: "The impact of clear-cutting may be reduced by leaving clusters of trees spaced no farther than 50 m apart. Logs and slash should be left for foraging sites, winter dens and subnivean travel routes."</p>
302	<p>Harris, M. 2004. The Importance of Competition Processes and Canopy Gaps in the Development of Old-Growth Pseudotsuga/Tsuga Forests. Seattle, WA: Univ. of WA. Master's Thesis; 101p.</p> <p>1 - Very Relevant to Jackson WHMP</p> <p>Available from UW library</p>

	<p>Notes a study that found light to be the most important factor in limiting seedling growth when PAR (photosynthetically active radiation) was less than 30% of full sun.</p> <p>Notes several studies that found no association between canopy openings and regeneration on the forest floor.</p> <p>Notes a study that found that canopy gaps were important for allowing regeneration of Tsuga and Abies establishment under Tsuga canopies, but not needed for regeneration of shade tolerant species beneath Pseudotsuga canopies.</p> <p>Due to the incidence of light angles at this latitude, locations of regeneration may be associated with canopy gaps, but may not be superimposed on the same location.</p> <p>Notes study (Parker et al 2002) that found that large gaps extending from the upper canopy to the understory are not necessarily associated with a large increase in light directly beneath the gap.</p> <p>Competition induced mortality appears to be higher between Tsuga and Abies in more open areas; but appears minimal among Tsuga regeneration on nurse logs in an area with many canopy trees and few gaps.</p>
279	<p>Humes, M.L., Hayes, J.P., Collopy, M.W. 1999. Bat activity in thinned, unthinned, and old-growth forests in western Oregon. J. Wildl. Manage., 63(2):553-561.</p> <p>3 - Not Relevant to Jackson WHMP</p>
150	<p>Jones, L., Holyan, J., Ray, S. 1993. Ecology and management of American martens in fragmented habitats of the Pacific Northwest. Progress Report: Fiscal Year 1993. USDA Forest Service Pacific NW Res. Stn., Forestry Sciences Laboratory, Olympia, WA.</p> <p>Marten used the largest trees in the vicinity as resting sites:</p> <ul style="list-style-type: none"> Live trees (44%), avg. 92.1 cm dbh and 35.7 m tall Snags (20%), avg. 81.6 cm dbh, 13.9 m tall Slash pile (% unclear) <p>Natal den sites had attributes similar to resting sites: a large live hemlock near a stream is typical.</p>
149	<p>Jones, L.L.C. 1990. Ecology and management of marten in fragmented habitats of the Pacific northwest. Progress Report: Fiscal Year 1991. USDA Forest Service Pacific NW Res. Stn., Forestry Sciences Laboratory, Olympia, WA.</p> <p>The first year of radio-telemetry field work on marten on the white River Ranger District, Mount Baker-Snoqualmie National Forest.</p> <p>Old growth western hemlock/silver fir forest use disproportionately, in proximity to streams or rivers, year-round.</p> <p>Home range size averaged 805 ha for females, 1571 ha for males.</p> <p>Resting sites:</p> <ul style="list-style-type: none"> Live trees (45%), used in accordance with their availability. Avg. 97 cm dbh, 32.3 m tall for western hemlock, Douglas-fir slightly larger and taller. Live hemlocks had numerous cavities originating as dead branches that had rotten into the bole, or from scars in the bark. Witch's brooms and heart rot cavities, broken-topped trees were occupied by martens Snags (23%) in decay class 4, with most of the bark missing, major branches gone, and soft, or hollow interiors. Avg. 81 cm dbh and 13.3 m tall

	<p>Log or slash piles (10%)</p> <p>2 natal dens found in large live hemlock trees.</p>
133	<p>Jones, L.L.C. 1991. Ecology and management of marten in fragmented habitats of the Pacific northwest. Progress Report: Fiscal Year 1991. USDA Forest Service Pacific NW Res. Stn., Forestry Sciences Laboratory, Olympia, WA.</p> <p>2 - Somewhat Relevant to Jackson WHMP</p> <p>Study involving radio-telemetry and camera monitoring in western Washington sites.</p> <p>Martens used old growth forests disproportionately, and used clearcuts less frequently than available in their home ranges. (Note, the study area lacked mature second-growth forests, 20 to 80 years old). Martens were usually located near streams.</p> <p>Resting sites included live trees (42%, of which 70% were western hemlock). Snags accounted for 23% of the resting sites. Manmade slash piles accounted for 11%. Large canopy trees were used according to their availability, although western hemlock was utilized more than Pacific silver fir. Average dbh of live tree resting sites was 100 cm. Average dbh for snags was 81 cm.</p> <p>Natal dens were similar to typical resting sites: large-diameter live trees (usually western hemlock) or snags, near water.</p>
228	<p>Linders, M.J., Stinson, D.W. 2006. Draft Washington state recovery plan for the western gray squirrel. Wildlife Program, WA Dept. Fish & Wildl. Olympia, WA. 99 pp.</p> <p>1 - Very Relevant to Jackson WHMP</p> <p>Management guidelines</p>
124	<p>Marcot, B.G., R.S. Holthausen, J. Teply and W.D. Carrier. 1991. Old-Growth Inventories: Status, Definitions, and Visions for the Future In: Ruggiero, L. F. et al, editors. Wildlife and Vegetation of Unmanaged Douglas-fir Forests. USDA Forest Service, GTR-PNW-285. pp 47-60.</p> <p>1 - Very Relevant to Jackson WHMP</p> <p>Provides definitions of Old-growth characteristics, cited by several authors as the basis for managing for PWP.</p> <p>Society of American Forests -</p> <p>25+ snags/ha > 6m tall.</p> <p>10+ snags/ha > 64cm dbh</p> <p>Old growth Definition Task Force -</p> <p>10+ snags/ ha > 51 cm dbh and > 4.6m tall.</p>
154	<p>Marshall, D.B. 1994. Status of the American Marten in Oregon and Washington. Unpublish Report. Portland, OR. Audubon Society of Portland. 46 p.</p> <p>2 - Somewhat Relevant to Jackson WHMP</p> <p>Literature review with section on timber harvest practices.</p> <p>Cites management recommendations of Corn and Raphael (1992) in Wyoming, and studies in California (Sierra Nevada): Martin and Barrett (1991), Hargis and McCullough (1984), Spencer (1981). See separate citations for these studies.</p> <p>Martin habitat requirements include high percentages of late-successional or mature and/or old-growth forests that can accommodate large home ranges. Habitat quality depends on mesic areas, high availability of prey, subnivean access where snow accumulates, a canopy level of at least 40%, and numerous denning sites. Denning sites include cavities in large snags and logs, and subterranean cavities under large logs, stumps and root wads. In the Pacific Northwest, martens use cavities in large diameter live trees and snags. Martens do not</p>

	<p>cross large open areas except when overhead cover is present, but will enter non-forested areas having cover in summer for berries.</p> <p>Forest fragmentation results in larger home range sizes and lower population sizes under late-successional or old growth conditions fall below the 30 to 50% level. Local extirpations then occur.</p>												
274	<p>North, M., Greenberg, J. 1998. Stand conditions associated with truffle abundance in western hemlock/Douglas-fir forests. <i>For. Ecol. And Manage.</i> 112:55-66.</p> <p>3 - Not Relevant to Jackson WHMP</p>												
284	<p>Olson, D.H., Hagar, J.C., Carey, A.B., Cissel, J.H., Swanson, F.J. 2001. Wildlife of Westside and high montane forests. In Johnson, D.H., O'Neill, T.A. <i>Wildlife-habitat relationships in Oregon and Washington</i>. Oregon State Univ. Press. Corvallis, OR. P. 187-212.</p> <p>2 - Somewhat Relevant to Jackson WHMP</p> <p>Patterns of bird communities in coniferous forests of western Oregon and Washington:</p> <ul style="list-style-type: none">• Majority of bird spp widely distributed within this zone• Avian community composition influenced by elevation, seral stage vegetation structure and composition, presence of water, and other special features.• Differences b/n seral stage most pronounced between very early open canopy (grass-forb-shrub) and closed canopy• Species richness of birds similar in early and late stages of forest development, and lowest in the structurally simple mid-seral stages of managed forests.• Key features influence presence of bird species: logs, rock substrates, litter, snags, large trees. Species that are most abundant in older forests will use early seral habitats if key structural features are present.• Abundance and diversity of birds positively correlated with the abundance of hardwood trees and shrubs, e.g. warbling vireos, MacGillivray's warbler, orange-crowned warbler, Wilson's warbler <p>Bird species associated with seral stages/vegetation height</p> <table><tr><th>Grass/forb trees (old growth)</th><th>Shrub/seedling</th><th>Sapling/pole</th><th>Small trees</th><th>Medium trees</th><th>Large & giant trees</th></tr><tr><td>61</td><td>92</td><td>98</td><td>130</td><td>140</td><td>140</td></tr></table> <p>Willow flycatcher, white-crowned sparrow, song sparrow, spotted towhee Pacific slope flycatcher, varied thrush, brown creeper, chestnut-backed chickadee, red-breasted nuthatch, hairy woodpecker Marbled murrelet, spotted owl, Vaux's swift</p> <ul style="list-style-type: none">• Diversity hotspots: old growth, riparian <p>Habitat elements</p> <ul style="list-style-type: none">• Surface rock, logs, duff/litter, snags, live trees, moss, cavities, shrubs, riparian <p>Forest Wildlife Assemblages</p> <ul style="list-style-type: none">• Examples: ground-dwelling small mammals, forest canopy mammals, cavity-nesting birds and mammals, terrestrial-breeding amphibians, pond-breeding amphibians, stream-breeding amphibians• Stream-breeding amphibians: torrent salamander, Cope's giant salamander, tailed frog, Pacific giant salamander• Terrestrial-breeding amphibians: Dunn's salamander, western red-backed, Van Dyke's. Some associated with rock (plethodontids) , some with downed wood (slender salamander, black salamander• Pond-breeders: red-legged frog, Cascades frog• Forest-floor small mammals: Trowbridge's shrew, southern red-backed vole, montane	Grass/forb trees (old growth)	Shrub/seedling	Sapling/pole	Small trees	Medium trees	Large & giant trees	61	92	98	130	140	140
Grass/forb trees (old growth)	Shrub/seedling	Sapling/pole	Small trees	Medium trees	Large & giant trees								
61	92	98	130	140	140								

	<p>shrew, deer mouse, forest deer mouse, shrew-mole, creeping vole, vagrant shrew (+ others)</p> <ul style="list-style-type: none"> • Arboreal rodent: northern flying squirrel, Douglas squirrel, Townsend's chipmunk • Good forest management leads to high diversity of small mammal and arboreal rodent assemblages <p>Forest management</p> <ul style="list-style-type: none"> • Federal: Northwest Forest Plan. Forest rotations and green tree retention levels matched to fire frequency intervals (100, 200 and 300 years) and intensities (15-50% retention)
325	<p>O'Neil, T.A., Johnson, D.H., Barrett, C., Trevithick, M., Bettinger, K.A., Kiilsgard, C., Vander heyden, M., Greda, E.A., Stinson, D., Marcot, B.G., Doran, P.J., Tank, S., Wunder, L. 2001. Matrixes for wildlife-habitat relationship in Oregon and Washington. In Johnson, D.H., O'Neil, T.A., dirs. Wildlife-habitat relationships in Oregon and Washington. Corvallis, OR: Oregon State Univ. Press.</p> <p>2 - Somewhat Relevant to Jackson WHMP</p> <p>Digital tables with compiled information on (1) wildlife-habitat types, e.g. forest type; (2) structural conditions, e.g. forest structure, grassland, wetland, etc.; (3) habitat elements, e.g. snags, CWD; (4) key ecological functions, (5) life history, (6) salmon-wildlife relationship, and (7) management activity links.</p>
14	<p>Public Utility District No. 1 of Snohomish County and City of Everett, Washington. 1988. Wildlife Habitat Management Plan, Henry M. Jackson Hydroelectric Project, 3 Vol., Paging various.</p> <p>1 - Very Relevant to Jackson WHMP</p>
70	<p>Rose, C.L., Marcot, B.G., Mellen, T.K. and others. 2001. Decaying wood in Pacific Northwest forest: concepts and tools for habitat management. In: Johnson, D.H., O'Neil, T.A. eds. Wildlife-habitat relationships in Oregon and Washington. Corvallis, OR: Oregon State University Press. Chapter 24.</p> <p>1 - Very Relevant to Jackson WHMP</p> <p>Since the publication of Thomas et al.³⁶⁹ and Brown,⁴⁸ new research has indicated that more snags and large down wood are needed to provide for the needs of fish, wildlife, and other ecosystem functions than was previously recommended by forest management guidelines in Washington and Oregon. For example, the density of cavity trees selected and used by cavity-nesters is higher than provided for in current management guidelines.^{53, 102} Reductions</p> <p>Habitat suitability for cavity-users is influenced by the size (diameter and height), abundance, density, distribution, species, and decay characteristics of snags.³⁰⁷ In addition, the structural condition of surrounding vegetation determines foraging opportunities.⁴⁰²</p> <p>Total snag densities were greatest at higher elevations: 15.1/ac (37.2/ha) in montane mixed-conifer forest and 14.6/ac (36.0/ha) in subalpine parks (Table 1). Snags were least dense in the drier wildlife habitat types on the eastside: 0.3/ac (0.8/ha) in western juniper woodland and 2.0/ac (5.0/ha) in eastside ponderosa pine (Table 1). Large snags were most abundant in montane mixed-conifer forest (3.8/ac; 9.6/ha) and in westside conifer-hardwood forest (2.2/ac; 5.5/ha), and least abundant in western juniper woodland (0.1/ac; 0.2/ha) and ponderosa pine (0.4/ac; 1.0/ha) (Table 1).</p> <p>A large proportion of the plots contained no snags</p>

	<p>or down wood, and a very small proportion of the plots contained extremely large accumulations of dead wood. Mean values for these skewed distributions must be interpreted with caution. The distribution of snags for the conifer alliance of westside conifer-hardwood forest (Figure 11) illustrate this pattern. In this wildlife habitat type, 39 percent of the area sampled had no snags.</p> <p>Several major lessons have been learned in the period 1979-1999 that have tested critical assumptions of these earlier management advisory models:</p> <ul style="list-style-type: none"> . Calculations of numbers of snags required by woodpeckers based on assessing their biological potential. (that is, summing numbers of snags used per pair, accounting for unused snags, and extrapolating snag numbers based on population density) is a flawed technique. Empirical studies are suggesting that snag numbers in areas used and selected by some wildlife species are far higher than those calculated by this technique.²²⁶ . Setting a goal of 40% of habitat capability for primary excavators, mainly woodpeckers,³⁶⁹ is likely to be insufficient for maintaining viable populations. . Numbers and sizes (dbh) of snags used and selected by secondary cavity-nesters often exceed those of primary cavity excavators. . Clumping of snags and down wood may be a natural pattern, and clumps may be selected by some species, so that providing only even distributions may be insufficient to meet all species needs. . Other forms of decaying wood, including hollow trees, natural tree cavities, peeling bark, and dead parts of live trees, as well as fungi and mistletoe associated with wood decay, all provide resources for wildlife, and should be considered along with snags and down wood in management guidelines. <p>In addition, it may be both biologically and operationally beneficial to create and preserve snags within patches of uncut trees, rather than to distribute them uniformly across stands.</p> <p>Trees topped above two branch whorls survive and develop new tops. Continued diameter growth in these trees provide higher values as wildlife snags. Large crooks formed in these trees also provide platform nest sites and create future breaking points to form a tall snag. The greater longevity of these live-topped trees should reduce the need to cause intentional mortality in leave trees in the future.</p> <p>Topped trees rapidly develop cavities throughout the bole. Live-topped trees develop cavities ten years after topping, with cavities forming first near the upper bole. The creation of live trees with cavity habitat is highly desirable, as it</p>
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	<p>allows cavity habitat to be maintained over longer periods.</p> <p>Big-leaf maple has relatively high survival and provides a high density of cavity sites.</p> <p>Notes on CWD:</p> <p>The volume of total and large down wood generally increases with forest development: large successional stages contained the largest concentration of both total and large down wood, although some young stands may inherit CWD and live trees from preceding stands. In westside forests, the volume of total and large down wood in the late stage usually was significantly different from the early and mid stages, but early and mid stages were usually not significantly different from one another. CWD has a longer lag time in forests than snags and is less likely to be disturbed by management activities.</p> <p>Estimates of mean total WD (>4.9 in large end, >6.6 ft long) volume in 3 successional stages of westside conifer-hardwood forest ranged from 2,169 to 3,233.8 cu ft/ac. Large WD (>19.7 in large end, >6.6 ft long) ranged from 1,408 to 2,469 cu ft/ac.</p> <p>Management tools and opportunities</p> <p>Retain large snags, large decadent trees, and logs from previous rotation. To reduce safety and operational hazards, cluster snags in patches rather than wide dispersal, and create snags from green trees after harvest.</p> <p>Green tree retention (10-40%) of living trees, including dominants, through next rotation. Green tree retention on a harvest cycle of 120 yrs proposed as a method to provide habitat for late successional spp in only 40-50 yrs. The DEMO program offers information on wildlife and vegetation response to green tree retention.</p> <p>Variable density thinning. Also, aggregated or "patch" retention of small forest patches instead of dispersed retention, is suggested.</p> <p>Thinning and long rotations promote stand development and, thus, larger trees available for dead wood creation.</p>
143	<p>Specifications for meeting habitat requirements for pileated woodpecker and pine marten. 1990. Mt. Baker-Snoqualmie National Forest. Final EIS - Land and Resource Management Plan, Appendix H. Seattle, WA:USDA Forest Service, PNW Region, p. H-16 to H-23.</p> <p>2 - Somewhat Relevant to Jackson WHMP</p> <p>May be out of date information, but see tables in Supportive Link</p>
169	<p>Spencer, W.D. 1981. Pine marten habitat preferences at Sagehen Creek, California. M.S. Thesis. Univ. of Calif., Berkeley, CA. 121pp.</p> <p>2 - Somewhat Relevant to Jackson WHMP</p> <p>For forest stands adjoining riparian areas and meadows, "timber harvest should be by single-tree selection (maintaining 40-50% canopy closure) or small group selection (<0.25 ha). At least 8 snags/ha >38 cm dbh, including 1 >70 cm dbh, should be retained, along with 6 logs/ha > 60 cm dbh. At least 12 fir trees/ha 70 cm dbh should be retained to provide for future snag recruitment."</p> <p>In more distant forest stands, "a greater variety of silvicultural practices are acceptable...where maintenance of habitat density and travel corridors are the major objectives. Clearcuts should be <100 m across with scattered trees left within them, and travel corridors of at least 30% canopy closure should be left connecting important habitats."</p>

	Cited in Marshall, 1994
135	<p>Spies, T.A., Franklin, J.F. 1988. Old growth and forest dynamics in the douglas-fir region of western Oregon and Washington. Nat. Areas. J. 8(3):190-201.</p> <p>2 - Somewhat Relevant to Jackson WHMP</p> <p>Provides interim definitions for old growth in the Douglas-fir and mixed conifer region of Washington, Oregon and northern California, based on minimal numbers and sizes of large live trees, canopy structure, snags and logs. For Douglas-fir on western hemlock sites (western hemlock, Pacific silver fir) stand characteristics are as follows:</p> <p>live trees: Two or more species with wide range of ages and sizes. Douglas-fir >8 per acre of trees >32 inches or >200 years old. Tolerant associates (western hemlock, western redcedar, Pacific silver fir, grand fir, or big-leaf maple) >12 per acre of trees >16 inches</p> <p>canopy: deep multi-layered canopy</p> <p>snags: conifer snags >7 per acre that are >20 inches in diameter and >15 ft. tall</p> <p>logs: Logs >15 tons per acre including 4 pieces per acre >24 inches in diameter and >50 ft. long</p>
285	<p>USDA Forest Service. 1994. Standards and Guidelines for Management of Habitat for Late-Successional and Old-Growth Forest Related Species Within the Range of the Northern Spotted Owl, Attachment A to the Record of Decision for Amendments to Forest Service and Bureau of Land Management Planning Documents Within the Range of the Northern Spotted Owl.</p> <p>1 - Very Relevant to Jackson WHMP</p> <p>Adequate numbers of large snags and green trees are especially critical for bats because these trees are used for maternity roosts, temporary night roosts, day roosts, and hibernacula. Large snags and green trees should be well distributed throughout the matrix because bats compete with primary excavators and other species that use cavities. Day and night roosts are often located at different sites, and migrating bats may roost under bark in small groups. Thermal stability within a roost site is important for bats, and large snags and green trees provide that stability. Individual bat colonies may use several roosts during a season as temperature and weather conditions change. Large, down logs with loose bark may also be used by some bats for roosting.</p> <p>Removal of snags following disturbance can reduce the carrying capacity for these species for many years.</p> <p>Regarding green tree areas, for many species, benefits will be greatest if trees are retained in patches rather than singly. Because very small patches do not provide suitable microclimates for many of these organisms, patches should generally be larger than 2.5 acres.</p> <p>To the extent possible, patches and dispersed retention should include the largest, oldest live trees, decadent or leaning trees, and hard snags occurring in the unit. Patches should be retained indefinitely.</p> <p>As a minimum, snags are to be retained within the harvest unit at levels sufficient to support species of cavity-nesting birds at 40 percent of potential population levels based on published guidelines and models. The objective is to meet the 40 percent minimum standard throughout the matrix, with per-acre requirements met on average areas no larger than 40 acres. To the extent possible, snag management within harvest units should occur within the areas of green-tree retention. The needs of bats should also be considered in these standards and guidelines as those needs become better known.</p>

	<p>Specifically, the Scientific Analysis Team recommends that no snags over 20 inches dbh be marked for cutting. The Scientific Analysis Team recognizes, however, that safety considerations may prevent always retaining all snags.</p> <p>Site-specific analysis, and application of a snag recruitment model (specifically, the Forest Service's Snag Recruitment Simulator) taking into account tree species, diameters, falling rates, and decay rates, will be required to determine appropriate tree and snag species mixes and densities. If snag requirements cannot be met, then harvest must not take place.</p> <p>Snag requirements are developed by the National Forests and BLM Districts for specific forest cover types, and these may be further broken down by geographic location. The intent is to tailor the requirements to those species that are actually expected to occur in an area.</p> <p>The most current available research will be used to determine to what degree the requirements for these other species are met by these snags or whether additional snags are needed to meet these other species objectives.</p>
71	<p>Van Pelt, R. 1995. Understory Tree Response to Canopy Gaps in Old-Growth Douglas-fir Forests of the Pacific Northwest. Seattle, WA. Univ. of WA. PhD Dissertation; 237p. 1 - Very Relevant to Jackson WHMP Master's thesis available from UW library.</p> <p>Variability in the canopy was highly correlated with understory light levels and shrub cover values.</p> <p>Spatial patterns of regeneration trees were poorly correlated with canopy height, canopy density and location of gaps</p> <p>Light environment is highest 18-20m north of the gap center.</p> <p>Understory trees that responded to gap formation did so within 5 years, but many did not show a response.</p> <p>Shrub and herb cover showed stronger correlation with canopy gaps and were more adaptable to changes in the canopy environment.</p> <p>Noted that Spies et al 1990 reported that median gap size in OG DF forests was 85m² (765ft²), small enough that only shade tolerant species can take advantage.</p> <p>Hemlock crowns are more densely packed with needles than Douglas-fir.</p> <p>High latitude of Pacific forests and the height of the canopy allow light to filter in at relatively high angles.</p> <p>Understory tree location was poorly correlated with gap location, but shrub location was better correlated with gap location.</p> <p>Several natural gaps were analyzed to determine the gap initiation year and cause, if possible. One gap nearly doubled in size over a 40 year period, with at least 3 separate events causing overstory tree mortality.</p> <p>Trees may take several years to reveal effect of release from competition when a neighbor dies.</p>

	<p>Highest branch growth of residual trees around experimental gaps (0.35ha) was by the third growing season and was south of center, where diffuse light levels were high, but direct light levels were low.</p> <p>Trees in direct light suffered higher rates of mortality and retained needles for a shorter duration.</p> <p>The northern part of the gap exhibited the greatest change in biological factors measured; this area had the highest soil light and soil temperature levels, and consequently the highest mortality and needle loss on surviving trees.</p>
298	<p>Vesho, I. 2000. Influence of Old-Growth Canopy Gaps on Microclimate, Litter Decomposition, and Soil Nitrogen Dynamics in Olympic National Park, WA. Seattle, WA. Univ. of WA Master's Thesis; 80 p. 2 - Somewhat Relevant to Jackson WHMP Available from UW library.</p> <p>Relevant geographically and temporally, but focuses primarily on the effect of canopy gaps on soil moisture and temperature, litter decomposition rates and soil nitrogen mineralization.</p>

Riparian Habitat

153	<p>Anthony, R. G., G. A. Green, E.D. Forsman & S.K. Mellen. 1996. Avian Abundance in Riparian Zones of Three Forest Types in the Cascade Mountains, Oregon. <i>Wilson Bull.</i> 108:280-291.</p> <p>3 - Not Relevant to Jackson WHMP</p>
204	<p>Beach, E.W., Halpern, C.B. 2001. Controls on conifer regeneration in managed riparian forests: effects of seed source, substrate, and vegetation. <i>Can. J. For. Res.</i> 31(3):471-482.</p> <p>2 - Somewhat Relevant to Jackson WHMP</p> <p>Field study in western WA testing hypothesis that seed availability rather than competitive interactions shapes patterns of conifer regen in managed riparian forests.</p> <p>Frequency and density of conifer regen were significantly greater within 100 m of remnant forest patches than at greater distances.. Where seed sources were present, regen positively associated with CWD and negatively associated with fine litter. Regen most abundant in plots with <10% herb or shrub layer. No relationship detected between regen density and overstory conifer or hardwood cover. Results suggest that in managed forests, conifer regen is largely limited by seed availability and only secondarily by competitive interactions or substrate conditions. Suggest GTR as an effective tool for increasing conifer regn in riparian zone.</p>
261	<p>Bisson, P.A. et al. 2002. Influence of site and landscape features on vertebrate assemblages in small streams. In: Johnson, A., Haynes, R. eds. <i>Proc. of the wood compatibility initiative workshop</i>. Gen Tech. Rep. PNW- GTR-563. Portland, OR: USDA Forest Service. Pac. NW. Res. Stn.</p> <p>3 - Not Relevant to Jackson WHMP</p> <p>Field study in 62 headwater streams on the Olympic Peninsula. Riparian Ecosystem Management Study (REMS).</p> <p>Site-level features included stream habitat type, channel substrate and riparian forest condition (canopy density, % riparian early-seral forest, % riparian mid-seral forest, % riparian late-seral forest). Landscape-level features included forest age (early-, mid-, late-seral), drainage characteristics (drainage density, watershed area), elevation, road density, and landslide frequency.</p> <p>Two major headwater vertebrate groups - fishes (cutthroat trout, torrent sculpin, coast range sculpin and amphibians(tailed frog, Cope's giant salamander, torrent salamander.</p> <p>Stream-dwelling amphibians influenced by riparian and watershed features and less affected by in-stream habitat. Stream-dwelling amphibians negatively affected by timber removal near streams. They preferred streams with late-seral riparian and uplands forests, low road density. Buffers of old-growth trees provided habitat refugia for some spp and were source areas for recolonization.</p> <p>The study did not establish a clear relationship b/n riparian forest characteristics and fish abundance in streams.</p> <p>Relationship b/n forest management and integrity of aquatic and riparian systems is complex, and it would be difficult to tailor management actions at the site level to produce desired changes in small stream-dwelling vertebrates at the population level. Changes in riparian forest at the landscape level, however, may influence populations. E.g., the percentage of a watershed in late-seral forest, the time since the last major disturbance, or road density may be important to aquatic- and riparian-associated vertebrates, but they are insufficient by themselves to explain population changes.</p>
73	<p>Castelle, A.J., Conolly, C., Emers, M., Metz, E.D., Meyer, S., Witter, M., Mauermann, S., Erickson, T., Cooke, S.S. 1992. Wetland Buffers: use and effectiveness. Olympia, WA: WA St. Dept. of Ecology, Shorelands & Coastal Zone Mgt. Prgm. Publ.# 92-10.</p>

	2 - Somewhat Relevant to Jackson WHMP Useful Buffer Zone guidelines
224	Emmingham, B., Chan, S., Mikowski, D., Owston, P., Bishaw, B. 2000. Silviculture practices for riparian forests in the Oregon coast range. Res. Contrib. 24. Forest Research Lab., College of Forestry, OR State Univ. 2 - Somewhat Relevant to Jackson WHMP Useful guidelines
85	Forest Ecosystem Management Assessment Team. 1993. Forest Ecosystem Management: An Ecological, Economic, and Social Assessment. 2 - Somewhat Relevant to Jackson WHMP This report is Appendix A of the DEIS on Management of Habitat for Late-Successional and Old-Growth Forest Related Species within the Range of the Northern Spotted Owl
250	Gregory, S.V. 1997. Riparian management in the 21st century. IN: Kohm, K, Franklin, J., eds. Creating a forestry for the 21st century. Washington DC: Island Press. Pp. 69-85. 2 - Somewhat Relevant to Jackson WHMP
287	Kauffman, J.B., Mahrt, M., Mahrt, L.A., Edge, W.D. 2001. Wildlife of riparian habitats. In Johnson, D.H., O'Neil, T.A., eds., Wildlife-habitat relationships in Oregon and Washington. OSU Press, Corvallis, OR. Pp. 361-388. 3 - Not Relevant to Jackson WHMP Review article; cites confusion of terms and definitions based on hydrologic, topographic, edaphic, and vegetative criteria. One unifying feature is their association with streams or rivers (lotic systems). Riparian zones are defined here at the three-dimensional zones of direct physical and biotic interactions between terrestrial and aquatic ecosystems; boundaries of the riparian zone extend outward to the limits of flooding and upward into the canopy of streamside vegetation. Keystone plants and animals: willows and cottonwoods, salmon, beaver Lengthy description of functions of riparian zones, use of riparian zones by different animal groups (herptiles, birds, mammals). Discussions of influence of beaver, and human influences. Management considerations: --Negative impacts of disturbances due to timber harvest, water diversion, flow regulation, agricultural practices, pesticide/herbicide application, livestock grazing, introduced predaceous species, invasive plant species. --Landscape-level management is required because physical and biotic processes in the floodplain do not operate independently of inputs from the surrounding landscape. --Simplification or reduction of woody riparian vegetation is especially harmful to birds' breeding requirements. Preservation of riparian habitats -- Often passive restoration (i.e. stop the activity that is degrading the riparian zone) is sufficient for self-restoration. But sometimes must do more than just eliminate human-induced alteration; also includes management to maintain natural functions, e.g., weed control, prescribed fire. Active ecological restoration -- Aim is to return riparian zones to fully functional conditions, recognizing that riparian systems are in a constant state of flux. Criticizes inappropriate artificial instream structures, reintroduction of extirpated species, creation of permanent surface water wetlands where natural wetlands were seasonal. These actions must be implemented to recognize the potential of the site and recover its natural ecosystem processes. Many examples of mis-management are cited (p.382).

102	<p>Knutson, K.L. and V. Naef. WDFW, June 1995. SNAGS: Management Recommendations for Washington's Priority Habitats. 137p.</p> <p>1 - Very Relevant to Jackson WHMP</p> <p>Information on snag tree management. Westside forests containing 4 snags/acre or more that are greater than 20" dbh are considered Priority Habitat.</p> <p>Approx. 102 species in Washington use snags; 56 species nest or den solely in cavities within dead or dying trees.</p> <p>*** the following 14 cavity-nesting species are Priority Species,</p> <p>***** Northern Spotted Owl is listed as endangered;</p> <p>***** The Pileated WP and Vaux's Swift are both Candidate Species for listing.</p> <p>***** The remainder are Priority Species, considered for listing:</p> <p>flamulated owl, purple martin, western bluebird, fisher, wood duck, Barrow's Goldeneye, common goldeneye, bufflehead, hooded merganser, marten and western gray squirrel.</p> <p>*** Natural ecosystems should provide the model for determining suitable numbers and characteristics of desired snags, i.e. average density and size found in unmanaged old-growth forests should serve as the targets for snag retention. Diverse, abundant and stable communities of snag-using species occur in unmanaged forests, particularly late-successional stands. Past use of minimums as standards has resulted in less habitat being provided than necessary, and hence continued population declines.</p> <p>Only old-growth stands were found to support 100% of the maximum potential population of primary cavity-nesters, so managing for averages based on these areas provides the best hope of retaining and increasing populations of snag dependent wildlife. Without such measures, the 56 cavity-dependent wildlife species will likely continue to decline in number, and may be listed as threatened or endangered.</p> <p>*** Models (i.e. Thomas et al. 1979) that have been used for the past 15 years have several problems, they only consider nesting requirements, not foraging or roosting and therefore appear to underestimate the number of snags needed.</p> <p>*** Additionally, these models may underestimate by assuming that meeting the needs of primary cavity excavators also meets the needs of other snag dependent species. In fact, secondary users may be more sensitive to snag densities than the primary nesters.</p> <p>Snags should be retained both individually and in clumps (including live trees and existing snags), if possible, and should be well distributed across the landscape. Clumps reflect the natural pattern of trees dying in patches from insects, small fires and disease. Clumping may also help to reduce impacts on logging operations.</p> <p>Artificial snag creation should not take the place of retaining existing snags.</p> <p>Snags in riparian areas are particularly important because several cavity-nesting species (wood duck, osprey, pileated wp) preferentially breed close to streams and wetlands.</p> <p>As a group, cavity-excavators prefer trees greater than 24 m (79ft) tall.</p> <p>Snags in decay stages 2-4 (7-125 yrs old) are most commonly used for nesting. At the start of stage 4 (51 years old) nesting use begins to decrease.</p> <p>Douglass-fir are the most commonly used nesting tree, but are also the most available in larger size classes. They tend to decay from the outside in are favored by weak excavators. Hemlock are more susceptible to heart rot and are therefore more attractive to woodpeckers, but stand for a shorter period.</p>
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	<p>Hardwoods tend to grow in irregular shapes and can produce cavities in the trunk or branches even while alive. Since they are much less common than conifers, they are particularly valuable wherever they are found.</p> <p>Audubon Society Christmas bird counts over 30 years have shown a decrease in the populations of the downy and hairy woodpeckers, as well as the northern flicker.</p> <p>Diameter is the most important distinguishing characteristic of snags used for nesting and foraging. Snags and decadent trees greater than 38 cm (15in) dbh are used by some species for nesting and foraging, larger diameter snags (>51 cm/20in dbh) are preferred and offer optimal nesting and foraging conditions. Taller snags are also preferred (>18m/59ft).</p> <p>When creating snags, trees should be topped (chainsaw was shown to be the most effective method) 15-25m (50-82ft) above the ground. Wind firm conifers at least 51 cm (20 in) dbh should be selected. Live trees should be reserved around the created snags to provide better protection for the snag as well as higher wildlife use.</p> <p>Retaining live green trees around created snags in harvested areas also moderates the microclimate and thus encourages seedling and shrub growth as well as increasing wildlife use of the clearcut.</p> <p>Contrary to common opinion, retained trees do not act as a source of pests for the new developing forest. They actually serve as refugee and inocula for invertebrate fauna and mycorrhiza-forming fungus that are essential components of a new stand.</p> <p>Riparian Habitat Area Minimum Widths are reported in Table 4 of the document.</p> <p>Salvage logging should not be conducted if an area is being managed for the benefit of wildlife.</p> <p>Link below is to App B showing averages and minimums for snags in the Western Hemlock series (when using this table, Mark Hitchcock reports the following, Lake Chaplain is 70% site class 2, 25% class3 and 5% class 1; Spada is 60% site class 3, 30% class 4, and 10% class 5)</p> <p>****SEE ALSO Y:\Regulatory Affairs\WILDLIFE\Relicensing_Study_Plans\SP6 Literature Review\Supporting Documents\Summary of Findings SP6 - Snags.xls</p> <p>AND Y:\Regulatory Affairs\WILDLIFE\Relicensing_Study_Plans\SP6 Literature Review\Supporting Documents\102 WDFW Snag Mgmt Recommendations App B.pdf</p>
74	<p>Knutson, K.L., Naef, V.L. 1997. Management recommendations for Washington's priority habitats: riparian. Olympia, WA: WA St. Dept. Fish & Wildl. 181 p.</p> <p>1 - Very Relevant to Jackson WHMP</p> <p>Management recommendations for very wide range of activities, including many related to habitat characteristics for fish and wildlife.</p> <p>Required habitat characteristics for riparian zone fish and wildlife habitats:</p> <ul style="list-style-type: none"> *Connectivity *Vegetation composition - A mosaic of successional stages and plant communities; in forested areas, a mixture of conifer and deciduous spp.in mixed age classes. Well developed herb and shrub layer. *Multiple canopy layers

	<ul style="list-style-type: none"> *Natural disturbance, e.g. flooding, channel meandering. *Snags *Woody debris, including large logs, stumps, root wads and branches in riparian zone and instream. *Shape - Irregular edge providing diverse interface between riparian and adjacent upland habitat types *Width - Appendix C provide information on riparian habitat functions and the widths needed to retain those functions. *Stream bank *Associated wetlands; oxbows and beaver ponds
14	<p>Public Utility District No. 1 of Snohomish County and City of Everett, Washington. 1988. Wildlife Habitat Management Plan, Henry M. Jackson Hydroelectric Project, 3 Vol., Paging various.</p> <p>1 - Very Relevant to Jackson WHMP</p>
81	<p>Richardson, J.S., Naiman, R.J., Swanson, F.J., Hibbs, D.E. 2005. Riparian communities associated with Pacific Northwest headwater streams: assemblages, processes, and uniqueness. J. Am. Water Res. Assn. 41(4):935-947.</p> <p>Riparian areas of large streams provide important habitat to many species and control many instream processes--but is the same true for the margins of small streams? This review considers riparian areas alongside small streams in forested, mountainous areas of the Pacific Northwest and asks if there are fundamental ecological differences from larger streams and from other regions and if there are consequences for management from any differences.</p>
234	<p>Waterhouse, F.L., A. S. Harestad and P. K. Ott. 2002. Use of Small Streams and Forest Gaps for Breeding Habitats by Winter Wrens in Coastal British Columbia. Northwest Sci. 76:335- 346.</p> <p>2 - Somewhat Relevant to Jackson WHMP</p> <p>Wrens selected streams $\leq 10\text{m}$ wide, even though those $< 5\text{m}$ wide tended to dry up during the breeding season.</p> <p>The area within 5m of stream banks was most important for winter wren nest sites.</p> <p>Canopy gaps were also found to be important habitat sources in both upslope and riparian areas due to the nature of gap creation (rootwads, stumps, down trees etc that are used as song perches).</p>
273	<p>Young, K.A. 2000. Riparian zone management in the Pacific Northwest: Who's cutting what? Env. Manage. 26(2):131-144.</p> <p>3 - Not Relevant to Jackson WHMP</p> <p>Paper assesses riparian zone management regulations in CA, OR, WA, BC.</p>

Right-of-Way Vegetation Management

180	<p>DNR. 1984. Stump sprouting related to time of cutting red alder. DNR Report 45. Washington Dept. Natural Resources. Forest Land Manage. Div. Contrib. No. 303. 22p.</p> <p>2 - Somewhat Relevant to Jackson WHMP</p> <p>Older field study on timing of alder cutting to reduce likelihood of stump sprouts; presents some useful control methods.</p>
14	<p>Public Utility District No. 1 of Snohomish County and City of Everett, Washington. 1988. Wildlife Habitat Management Plan, Henry M. Jackson Hydroelectric Project, 3 Vol., Paging various.</p> <p>1 - Very Relevant to Jackson WHMP</p>
117	<p>Debell, D.S. and Turpin, T.C. 1989. Control of red alder by cutting. USDA Forest Service. Pacific Northwest Res. Station. Research Paper PNW-RP-414.</p> <p>1 - Very Relevant to Jackson WHMP</p> <p>Best to cut alder in June or July to ensure that stump dies and avoid stump sprouts. Easier to kill older trees (6 to 10 years old) than younger trees (4 years old).</p> <p>Note earlier DNR study (1984). August cutting recommended in addition to June-July.</p>

Second Growth Forest / Overstory Management (including gaps and GTAs)

307	<p>Altman, B., Hagar, J. 2006. Rainforest birds: a land manager's guide to breeding bird habitat in young conifer forests in the Pacific Northwest. U.S. Geological Survey, Sci. Investigations Report 2006-5304. 60 p.</p> <p>2 - Somewhat Relevant to Jackson WHMP</p> <p>Guide presents recommendations on the habitat conditions and features needed by breeding birds, and how breeding bird species respond to particular management activities.</p> <p>Effects of forest fragmentation.</p> <p>Patch size: Most birds that breed in young forests have fairly small territories, <5 ha per pair, but there are some exceptions. See linked table Some forest bird spp require patches of contiguous habitat much larger than their territory to be able to maintain a viable population. These spp are referred to as forest interior spp, or area-sensitive spp. Including brown creeper, chestnut-backed chickadee, golden-crowned kinglet, pileated woodpecker, red-breasted nuthatch, varied thrush, winter wren, and possibly Pacific-slope flycatcher. All these spp also occur in lower abundance in the latter stages of young forests (i.e. mid-successional) where it is suspected that the same area-sensitivity is applicable.</p> <p>Edge: Variable effects on different species, and not well understood.</p> <p>Connectivity: For birds associated with young conifer forests, less concern about connectivity unless the intervening habitat is non-forest.</p> <p>Deciduous vegetation: Highly important for 2 reasons: higher availability of cavities, and higher insect abundance.</p> <p>Strategizing among desired habitat features and bird spp. Often emphasize habitat needs of special status birds. May emphasize habitat diversity or bird species richness. A sound strategy combines these 2 approaches. like cascara or elderberry for band-tailed pigeon. Additionally, the open canopy in a large patch of the forest could be expanded, leaving scattered trees to provide habitat for olive-sided flycatcher.</p> <p>Planning for old forest habitat: Manage tree density early in stand development, before canopy closure to maintain a diverse stand structure throughout the life of the stand.</p> <p>Thinning. Short-term goals may be to increase structural diversity, or to create habitat for a particular set of spp. Long-term goals may include creating structural features typical of old forests, e.g. accelerate the growth of residual trees.</p> <p>Achieving old forest structure through thinning. Summarizes other studies. Thinning affects stem size, crown characteristics and vigor of trees, retention of lateral branches. Increase stand-level structural diversity, shrub response to light, tree seedling establishment.</p> <p>Bird response to thinning. See link</p> <p>Desired habitat features for breeding birds in young conifer forests. See link.</p> <p>Bird response to retention of forest structure. Only preliminary data available. Doesn't ameliorate for negative effects on the abundance of canopy dwelling spp like golden-crowned kinglet and hermit warbler.</p>
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	<p>Habitat augmentation: **brush/slash piles used by American robin, dark-eyed junco, western bluebird, house wren, song sparrow, winter wren **snag cration **nest boxes</p> <p>Useful appendices: Successional stage nesting habitat relationships of breeding bird spp</p> <p>Relationships between thinning and breeding bird species abundance</p>
39	<p>Andrews, L.S., Perkins, J.P., Poage, N.J., Tappeiner II, J.C. 2005. Silvicultural approaches to develop northern spotted owl nesting sites, Central Coast Ranges, Oregon. West. J. Appl. Forestry 20(1):13-27. 2 - Somewhat Relevant to Jackson WHMP</p> <p>Review articles and computer simulation that uses tree growth model ORGANON for central coast range region. Explores a range of 32 management scenarios for Douglas-fir stands 50 y.o. (170-247 tpa) and estimated which scenarios promoted the development of forest patches that emulate the species mix and diameter distributions of known spotted owl nest sites.</p> <p>It was difficult to alter the development trajectory of stands first managed at 50 yrs. Management earlier in the development of natural stands would have promoted the growth of large trees with deep crowns, reduced overstory density to levels consistent with those of older forests, promote understory development including shrub layers, and lead to greater differentiation in diameter distributions in a shorter time frame.</p> <p>Without silvicultural action (or natural disturbances), stands did not develop nesting habitat features within the 160 year simulation.</p> <p>In most simulation trials, commercial thinning from below at 50 yrs. Heavy thinning retained 30-45 tpa, light thinning retained 126-149 tpa. Retained hardwoods, shade-tolerant conifers and large-diameter Douglas-fir. At 80 yrs simulated thinning across a range of densities while thinning from above, below, or proportionally. At 120 yrs, modeled a uniform proportional thinning.</p> <p>Heavy to moderate thinning with extended rotations appeared to promote the development of spotted owl nest habitat while shortening the duration of the least diverse (for wildlife) stage of stand development. Stands also required production of snags and coarse woody debris under these scenarios.</p> <p>A number of simulation pathways were discovered leading to suitable nest habitat features, suggesting that stand management can follow multiple routes from dense young stands to structures similar to old growth forests.</p> <p>Management suggestions: **Early commercial thinning, <50y.o. **Low overstory density promotes deep canopies , large-diameter branches, establishment of understory trees. Many naturally regen old-growth stands in the Coast Ranges appear to have initially developed at low stocking densities (aprox. 50 tpa) with gradual and ongoing ingrowth, probably owing to periodic and relatively intense wildfire events. Heavy thinning in young stands could be used to promote structures that emulate old-growth stands. **Multiple entries that thin both canopy layers may be required to optimize understory development when light or moderate thinning is applied, to avoid crown closure. **Short-term drawbacks to heavy thinning: As surface drying increases, development of brush fields or invasion by exotic plants may happen. **Heavy thinning of dense, developing young stands increases the potential for windthrow. If windthrow is expected, incorporate it into silvicultural planning. Select leave trees with the</p>

	<p>lowest H/D ratios. Several entries can be used to thin stands in stages to reduce windthrow damage. Low H/D ratios can be promoted through maintaining low initial stocking densities and/or by early stand thinning.</p> <p>**Variable-density thinning for structural heterogeneity in which intermediate-canopy trees can be released and regeneration, including underplantings, is encouraged. VDT emulates suppression mortality (light thinning), fine-scale disturbance (heavy thinning), and coarse-scale disturbance (patch cutting) within stands.</p> <p>**Culture trees in young low-density stands with the potential for legacy structures: trees with the lowest H/D ratios, multiple large limbs and potential for epicormic branching. Simulations predict that heaving thinning at age class 50 yrs may develop these legacy surrogates more quickly.</p>
176	<p>Artman, V. L. 2002. Effects of Commercial Thinning on Breeding Bird Populations in Western Hemlock Forests. <i>Am. Midl. Nat.</i> 149:225-232.</p> <p>2 - Somewhat Relevant to Jackson WHMP</p> <p>Compares bird populations and habitat structure in commercially-thinned and unthinned western hemlock stands on a tree farm in Pierce Co. 45 - 55 yo naturally-regenerated western hemlock stands (1270 live tph). CT treatments applied 3 to 5 yr before data collection; removed trees <30 cm dbh, resulting in 466 live tph. Canopy cover reduced from 89% to 73%. Small dead trees (<30 cm) almost as abundant as small live trees in unthinned stands--CT knocked the small dead tree inventory down to 76 tph. Snags >30 cm dbh reduced from 9 to 6 tph (not significantly different).</p> <p>Understory forb, grass and tree seedling components increased significantly post-CT. Moss, fern, shrub no significant difference.</p> <p>CWD volume increased post-CT</p> <p>12 bird species evaluated in this study. Total bird density did not differ between pre- and post-CT. Several bird spp responded positively to this CT: winter wren, dark-eyed junco, red-breasted nuthatch, chestnut-backed chickadee. Unclear why the latter 2 (cavity-nesters) increased post-CT. Similar result for these 2 spp reported by Hagar et al. (1996).</p> <p>Suggests managing with a mosaic of stand conditions (age classes and silvicultural treatments) to satisfy needs of most species. Repeated thinnings may be needed to maintain the mix of habitat conditions through a rotation.</p>
114	<p>Aubry, K.B. 1999. Amphibians in managed, second-growth Douglas-fir forests. <i>J. Wildl. Manage.</i> 64(4):1041-1052.</p> <p>2 - Somewhat Relevant to Jackson WHMP</p> <p>Second-growth timber stands managed for timber production had the same amphibian species present in unmanaged Douglas-fir stands. However, higher proportions of northwestern salamanders and western redback salamanders, and much lower proportions of tailed frogs were present in managed forests. No evidence that amphibian abundance was influenced by the amount of CWD, however, CWD in managed stands was not substantially lower than in unmanaged forests for any age classes in this study.</p> <p>The oldest age classes had the highest amphibian species richness, total biomass and total abundance, and higher abundances of ensatina and red-legged frog.</p> <p>Recommends thinning closed-canopy stands and extending rotation in managed stands.</p>
214	<p>Aubry, K.B., Halpern, C.B., Maguire, D.A. 2004. Ecological effects of variable-retention harvests in the northwestern United States: the DEMO study. <i>For. Snow Landsc. Res.</i> 78(1/2):119-137.</p> <p>1 - Very Relevant to Jackson WHMP</p> <p>DEMO study (Demonstration of Ecosystem Management Options) conducted in 6 locations in</p>

	<p>sw OR and WA Douglas-fir stands ranging from 65 to 170 y.o. Data were collected prior to harvest (1994-1996), harvests in 1997-1998, initial post-treatment sampling completed in 2001.</p> <p>6 treatments on 13 ha unit, representing green tree retention systems.</p> <p>**100% retention (no harvest)</p> <p>**75% aggregated retention (all merch trees in three 1-ha circles were harvested--25% of the treatment unit)</p> <p>**40% aggregated retention (five 1-ha circles retained - 40% of the treatment unit - and all merch trees in the surrounding matrix were harvested)</p> <p>**40% dispersed retention (dominant and co-dom trees retained in an even distribution throughout the unit. In each block, the basal area retained was equal to that retained in the 5 patches of the corresponding 40% aggregated-retention treatment)</p> <p>**15% aggregated retention (two 1-ha circles were retained - 15% of the treatment unit - and all merch trees in the surrounding matrix were harvested.</p> <p>**15% dispersed retention (dominant and co-dom trees retained in an even distribution throughout the treatment unit. In each block, the basal area retained was equal to that retained in the two patches of the corresponding 15% aggregated-retention treatment.)</p> <p>Post-harvest treatment:</p> <p>**6.5 snags/ha created in all harvested areas</p> <p>**Pre-existing CWD retained, but no prescription implemented to create additional material.</p> <p>**Reforestation (mix of spp) to achieve min. stocking of 312 tph at 5 yrs post-harvest</p> <p>Response variables</p> <p>**overstory and understory vegetation - will examine effects of GTR on forest structure and composition, and quantify veg changes to aid in understanding responses of associated organisms and processes.</p> <p>**ectomycorrhizal fungi</p> <p>**canopy arthropods</p> <p>**amphibians and forest-floor small mammals</p> <p>**bats</p> <p>**breeding birds</p> <p>Pre-publication summaries:</p> <p>Overstory and understory vegetation. Most groups of forest understory plants declined in abundance and richness more at 15 than at 40% retention. Changes within 1-ha aggregates were small on average, and declines in adjacent harvested areas were greater than those in the corresponding dispersed treatments. Forest herbs declined on the edges of the 1-ha aggregates. Late-seral herbs more frequently extirpated from harvested plots in the aggregated treatments than from plots in the dispersed treatments.</p> <p>Salamanders. Little evidence that level or pattern of retention strongly influenced salamander populations during the first few yrs post-harvest. Within aggregated-retention treatments, salamanders more frequently captured in uncut than in cut areas. Salamanders most abundant in areas where CWD and/or herb cover were high.</p> <p>Small mammals. Pattern of retention did not have consistently strong effects on small mammal abundance or community comp. Initial results indicate that 1-ha aggregates may function as short-term refuges for several interior-forest spp: red-backed voles.</p> <p>Bats. Variable-retention treatments created forest openings/reduce canopy density and increased use by some bat spp--perhaps concentrated their use in these openings. Furthermore, greatest impact on bat populations is probably loss of large trees and snags roosting habitat.</p> <p>Breeding birds. Variable responses depending on the species. In general, birds that feed or</p>
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	<p>nest in tree canopy or feed in bark decreased at greater harvest levels, whereas spp associated with forest-edge or open habitats increased.</p> <p>Second round of post-treatment veg sampling scheduled for 2003 and 2004.</p> <p>For summary reports from individual studies see http://www.cfr.washington.edu.research.demo/research/r_invert.htm</p> <p>IUFRO meeting on Innovative Experiments for Sustainable forestry in Aug. 2004 in Portland</p>
235	<p>Aubry, K.B., M.P. Amaranthus, J. D. White et al. 1999. Evaluating the Effects of Varying Levels and Patterns of Green-tree Retention: Experimental Design of the DEMO Study. Northwest Sci. 73: 12-26. 2- Somewhat Relevant to Jackson WHMP</p> <p>Aggregated retention is thought to be more effective at maintaining a broad array of structural elements, such as multiple canopy layers and understory vegetation, and snags of various sizes and decay classes that would not be possible in dispersed retention systems.</p> <p>Intact patches of habitat also act as refugia for organisms that will recolonize the harvest unit.</p> <p>Study set-up: *Snags that were deemed safe to work around were retained. *6.5 additional dominant/co-dominant green trees/ha were retained for snag creation.</p>
43	<p>Aubry, K.B., Raley, C.M. 2002. The pileated woodpecker as a keystone habitat modifier in the Pacific Northwest. In W.F. Laudenslayer, Jr. (and others), tech. coords. Proceedings of the Symp. on the Ecology and Management of Dead Wood in Western Forests. PSW-GTA-181. Albany, CA: US Forest Service, Pacific SW Res. Stn. pp. 257-274. 1 - Very Relevant to Jackson WHMP</p> <p>Recommendations for forest management in matrix lands covered by the NW Forest Plan:</p> <p>retain 15%+ of the harvested area as green tree reserves; 70% of which should be clumps 0.2 to 1.0 ha in size, the remainder dispersed either individually or small clumps > 0.2 ha in size. These clumps & dispersed groupings should be comprised of the largest, oldest, decadent or leaning trees and hard snags occurring within the unit. Snag management would primarily occur within these areas of green-tree retention.</p> <p>Table 3 provides CWD recommendations.</p>
19	<p>Aubry, Keith B. and Catherine M. Raley. Landscape-Level Responses of Pileated Woodpeckers to Forest Management and Fragmentation: A Pilot Study. Progress Report 1990 and 1991. USDA Forest Service PNW Research Station. January 8, 1992. 73p. 1 - Very Relevant to Jackson WHMP</p> <p>Half of all PWP nest cavities were in snags with broken tops, and half in live trees with broken tops. 75% were in Hemlock, 25% in Cedar. Avg DBH of all nest trees was 97.0cm, and nest cavities averaged 37.6m high. 73% of all roost cavities were in Hemlock, 27% in Cedar. Mean number of ALL decadent trees greater than 5m tall was 22.33/ha, mean number of snags alone was 20.55/ha. Logs were relatively unimportant as a food source in this study area.</p>
322	<p>Bailey, J.D., Tappeiner, J.C. 1998. Effects of thinning on structural development in 40- to 100-year-old Douglas-fir stands in western Oregon. For. Ecol. And Management 108:99-113. 2 - Somewhat Relevant to Jackson WHMP</p> <p>Retrospective study of stands that had been thinned for timber production 10-24 years before the study. At the time of this study, thinned stands had a wide range of density (mean 173 tpa, range 72-346), basal area (mean m2/ac, range 20-58) and relative density (mean 0.37, range 0.23-0.60).</p> <p>Conclusions: Thinning young Douglas-fir stands will hasten the development of multistory stands by</p>

	recruitment of conifer regeneration in the understory as well as by enabling the survival of small overstory trees and growth of advanced understory regeneration. Thinning will also help develop the shrub layer by increasing tall shrub stem density and cover of some low shrubs.
115	<p>BC Ministry of Environment and BC Ministry of Forests. 1993. Guidelines for maintaining biodiversity during juvenile spacing. BC Environment. Canada-British Columbia Forest Resource Development Agreement FRDA II.VI.</p> <p>2 - Somewhat Relevant to Jackson WHMP</p> <p>General basic descriptions of habitat features associated with biodiversity, with a few useful concepts for restocking at the stand level:</p> <p>Retain 5-10 live wildlife trees/hectare, 3 of which should be within the upper 10% of the diameter range of the stand</p> <p>Retain wildlife trees in small groups, at the edge of surrounding forest to avoid safety and operational conflicts. Isolated trees more susceptible to windthrow, offer less cover for wildlife.</p> <p>All stumps greater than 25 cm diameter, less than 3 m in height should be retained for woodpecker foraging.</p> <p>Cut shrubs taller than 3 m to promote coppicing and improve browse.</p> <p>Leave pre-existing wildlife trails unobstructed through directional falling and/or slash removal.</p> <p>Wider or patchy spacing in areas adjacent to water to encourage growth of woody forage species. Patchy spacing with some areas of higher density, will provide cover.</p> <p>Wider spacing adjacent to deciduous patches to promote forage species.</p> <p>Examples of contract specs</p>
314	<p>Beese, W.J., Dunsworth, B.G., Smith, N.J. 2005. Variable-retention adaptive management experiments: testing new approaches for managing British Columbia's coastal forests. In Peterson, C.D., Maguire, D.A., eds. Balancing ecosystem values: innovative experiments for sustainable forestry. Gen. Tech. Rep. PNW-GTR-635. Portland, OR: USDA Forest Service, Pac. NW Res. Stn. P. 55-64.</p> <p>Weyerhaeuser's BC "Coast Forest Strategy". Variable retention to enhance structural diversity. Experiments began in 2001.</p> <p>Experimental Design:</p> <ol style="list-style-type: none"> 1. Group retention: 10%, 20% and 30%; groups range in size from 0.2 to 0.5 ha. 2. Dispersed retention: 5%, 10% and 30%. Single trees to small groups up to 0.1 ha. 3. Group size: Large groups (0.8 to 1.2 ha), small groups (0.2 - 0.5 ha) and dispersed trees (single trees to very small groups to up to 0.1 ha); the retention level is 15% for all treatments. 4. Group removal - short/long cycle: Groups removal on short cutting cycle (5 to 7 yrs), group removal on long cutting cycle (20 to 30 years), groups in both treatments range in size from 0.1 to 1.0 ha. 5. Riparian retention: 0%, 15% and 50% of the length of small streams w/in treatments are covered by groups retention (i.e. 0.25 ha or larger groups); a retention level of 15% is maintained w/in all stream catchments. <p>Monitoring of live trees, snags, CWD, cover layers, dominant shrub and herb spp, selected wildlife spp monitoring, growth and yield monitoring, windthrow monitoring.</p>
321	<p>Beggs, L.R., Puettmann, K.J., Tucker, G.F. 2005. Vegetation response to alternative thinning treatments in young Douglas-fir stands. In Peterson, C.E., Maguire, D.A., eds. Balancing Ecosystem values: innovative experiments for sustainable forestry. Gen. Tech. Rep. PNW-GTR-635. USDA Forest Service, Portland, OR p. 243-248.</p>

	<p>2 - Somewhat Relevant to Jackson WHMP</p> <p>Part of the Young Stand Thinning and Diversity Study. 4 replications of 4 thinning treatments initiated in 1995.(avg. 30 ha each) in 30- to 50-yo Douglas fir stands. Uncut control, heavy thin, light thin, and a light thin with gaps..Unlike traditional CT, this study maintained overstory diversity by specifically retaining hardwoods and conifer spp other than Douglas-fir.</p> <p>Results of vegetation data indicate that only the heavy thinning maintained open canopies for multiple years and accelerated development of large trees. Thinning did not result in higher mortality rates, but decreased density-related mortality of Douglas-fir. Mortality was low for nondominant overstory trees that were retained. Vertical canopy structure did not respond immediately to thinning.</p>
48	<p>Beggs, L.R. 2004. Vegetation response following thinning in young Douglas-fir forests of western Oregon: can thinning accelerate development of late-successional structure and composition? Corvallis, OR. Oregon State University. Master's thesis. 95p.</p> <p>1 - Very Relevant to Jackson WHMP</p> <p>Field study that concludes that some types of thinning can place young managed stands on an accelerated trajectory toward late-successional attributes such as large diameter trees. 5 to 7 yrs following light (standard commercial thinning) thinning, canopy cover no longer differed from Control.</p> <p>Thinnings resulted in initial declines of bryophytes, tall shrubs and low shrubs followed by subsequent recovery and growth. Release of early seral-stage herbs by 5-7 yrs post-treatment. The addition of gaps generated plant assemblages that differed across the gradient from the gap to the thinned forest matrix. Concludes that thinning with gaps can hasten late-successional understory development.</p>
289	<p>Bonar, R.L. 1995. Alberta Guidelines for Retention of Residual Trees in Cutovers and Examples of Implementation in Forest Harvesting In: Bradford, P., T. Manning and B. l'Anson eds. Wildlife Tree/Stand-Level Biodiversity Workshop Proceedings. Victoria, B.C. October 1995. 67-70.</p> <p>2 - Somewhat Relevant to Jackson WHMP</p> <p>Post-harvest activities including site inspections, site preparation, planting, surveys, and tending will be allowed regardless of the tree retention guidelines used during harvesting. A reasonable time period (30 days) should elapse following harvest to allow unsafe trees to fall.</p> <p>High stumping with machinery can be used to convert dangerous snags to safe snags.</p> <p>Many companies now identify concentrations of dead trees and include them in no work areas within or outside of cutting unit boundaries.</p>
236	<p>Brett, T.A. 1997. Habitat Associations of Woodpeckers in Managed Forests of the Southern Oregon Cascades. Corvallis, OR, USA. Oregon State Univ. Master's Thesis; 95p.</p> <p>1 - Very Relevant to Jackson WHMP</p> <p>no PUD copy - available from OSU library.</p> <p>Previous research has shown that woodpeckers select for the tallest and largest snags available in all forest types.</p> <p>Higher nest cavities are believed to reduce predation.</p> <p>Recommend providing for the maintenance of 3 to 11 large (>50cm dbh) tall snags/acre depending on site conditions.</p> <p>Author predicts that Nietro 1985 recommendations are too low to sustain viable populations of cavity nesters and notes that another study shows that a majority of biologist believe that current guidelines for snag management are inadequate to maintain target populations of woodpeckers.</p>

	<p>For nest trees of all 7 species of cavity nesters present, average nest tree dbh = 79cm.</p> <p>Of 163 nest trees found over the 2 year study, 14% were decay class I, 45% class II, 30% class III, 10% class IV.</p> <p>Red-breasted Sapsucker: Nest trees had mean dbh of 80.5cm (random trees were 42.1 cm). Mean Nest ht = 20.4m mean Tree ht = 27.5m Predicted through logistic regression that for each 10cm increase in dbh, likelihood of use increases 10.5x.</p> <p>Hairy Woodpecker: Mean nest tree dbh = 80.4 cm (random = 42.1cm) Mean Nest ht = 18.6m mean Tree ht = 28.0m Predicted through logistic regression that for each 10cm increase in dbh, likelihood of use increases 10.4x. Decay class III snags were 16.4x more likely to be used for nesting than class IV.</p> <p>Northern Flicker: Mean nest tree dbh = 77.7 cm (random = 42.1cm) Mean Nest ht = 14.3m mean Tree ht = 19.7m Predicted through logistic regression that for each 10cm increase in dbh, likelihood of use increases 10.2x.</p> <p>Management emphasis should be placed on maintaining larger snags because they provide more foraging substrate, more available nest cavity potential and remain standing longer.</p> <p>Hairy WP were more associated with class III snags; Flickers and RB Sapsuckers were more associated with snags having broken tops.</p> <p>Habitat edges were chosen more often than random for nest site location. RB sapsuckers chose these areas for more than 33% of nest sites found; flickers (24%) and hairy WP (19%) also used these areas more than random (7%), but to a lesser degree than the sapsucker.</p> <p>Openings and open-canopy forests were found to have greater abundance of woodpecker nests, several past studies have also found that woodpeckers will nest in young regenerating forests if adequate numbers and sizes of snags are present.</p> <p>Landscape analysis revealed that woodpecker nest densities were higher in areas with greater habitat complexity (specifically patch heterogeneity and edge habitat).</p> <p>** Recommends snags greater than 80cm be retained in harvest units. This is the average diameter of nest tree used by the 3 species studied.</p> <p>Providing snags larger than the average is preferable as they provide more suitable habitat over the long run.</p> <p>** Recommends using alternatives techniques over a broad landscape, such as partial and shelterwood cuts. Small 20 to 30 acre patches created over a landscape would create habitat diversity but still maintain the integrity of the forest matrix.</p> <p>Small pockets of armillaria root rot could be preserved (they spread at about 1m/yr) to provide</p>
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	a continuous supply of nesting habitat.
246	<p>Brodie, A.W., Bowering, M, Jaross, W., Reimer, D, Lu, B. 2006 Combining management goals of wildlife habitat conservation and revenue on Washington state trust lands. In Harrington, T.B., G.E. Nicholas, tech. eds. Managing for wildlife habitat in west-side production forests. Gen. Tech. Rep. PNW-GTR-695. Portland, OR:USDA Forest Service, Pac. NW Res. Stn. P.67-80.</p> <p>2 - Somewhat Relevant to Jackson WHMP</p> <p>DNR paper describes forest modeling and silvicultural analysis, conducted as part of sustainable harvest calculation, with focus on management strategies of the spotted owl HCP. Biological habitat targets were taken from the HCP:</p> <ul style="list-style-type: none"> *At least 31 tpa >21 inches dbh *At least 15 tpa >31 inches dbh *Minimum 70% canopy closure *Minimum 5% ground cover of CWD <p>Operational target conditions:</p> <ul style="list-style-type: none"> *Height/diameter ratios of the residual stand must be less than 100 *Live crown ratio must be greater than 45% *Minimum thinning harvest of at least 8000 bf/ac <p>Economic targets:</p> <ul style="list-style-type: none"> *The earliest time at which they will meet the forest structural targets *The max NPV returns to DNR at the time of final commercial thinning <p>Treatments included a range of planting densities (22 to 750 tpa), PCT or not, fertilization, commercial thinning with 1, 2 or 3 entries, leaving a wide range of residual trees per acre (45 to 175). From this simulation, DNR screened treatment combinations that would produced a residual stand with high quality nesting habitat at some point in the 150 year projection. The residual stand and treatment had to meet the operational and economic criteria as well. The qualified treatments were used as input variables for a landscape simulation model to identify regimes that would qualify as "biodiversity pathways", after Carey et al (1996).</p> <p>Biodiversity pathway regimes do not produce economic returns at the stand level equivalent to commercial even-age silviculture. On site class III or higher sites, the highest ranking regimes had initial planting densities of 300 to 650 tpa, did not receive PCT (except on DF site class III) and had 2 commercial thinnings, at 30-40 years with a residual density of 125 - 175 tpa, and at 10-20 years later with a residual density of 45 tpa. These stands achieved desired structural condition at age 90 to 150 years.</p> <p>The most successful strategy found to maximize NPV while accelerating target structural conditions employed first CT at 30-40 years (150 tpa, RD 35-45), followed by second CT 10-20 years later to RD 20-25 (45-50 tpa).</p> <p>On site class IV or poorer, the highest ranking regimes were characterized by lower initial stocking (except DF Class IV) from 200-300 tpa, no PCT and only one thinning entry at 40-55 years, leaving a residual density of 45 tpa. These stands took between 140 and 150 years to reach the desired structural condition.</p> <p>Caveat: The simulation didn't address canopy closure. Heavy thinnings in young forest reduce canopy closure and thus habitat quality for spotted owls; the simulation didn't address the recovery of canopy closure. Also, this simulation didn't address spatial arrangement of residual trees; the likely use of VDT for biodiversity thinning as acknowledged but not tested in this study.</p>
329	<p>Brown, E. R., tech. ed. 1985. Management of Wildlife and fish habitats in forests of western Oregon and Washington. U.S. Forest Service ubl. No. \$6-F&WL - 192-1985. Portland, OR.</p>

	<p>1 - Very Relevant to Jackson WHMP</p> <p>Chapters in this document provide the basis for WHMP management techniques dealing with timber harvest, silviculture, deer forage, snag and coarse woody debris management.</p>
119	<p>Buchanan, J.B. and Swedeen, P. 2005. Final briefing report to the Washington state Forest Practices Board regarding spotted owl status and Forest Practices Rules. WA Dept. Fish and Wildlife. Olympia, WA.</p> <p>3 - Not Relevant to Jackson WHMP</p> <p>Summary of spotted owl status, biology, Forest Practices rules. Landscape-level summary, with discussions of outstanding issues, such as use of management circles vs. landscape management.</p>
280	<p>Buermeyer, K.R., Harrington, C.A. 2002. Fate of overstory trees and patterns on regeneration 12 years after clearcutting with reserve trees in southwest Washington. West. J. Appl. For. 17(2):78-85.</p> <p>2 - Somewhat Relevant to Jackson WHMP</p> <p>Status of overstory trees and regen 12 yr after a clearcut harvest with reserve trees in an even-aged Douglas-fir stand in sw WA. Two areas within the harvest unit had been thinned 15 and 34 yr before clearcutting. Lightly-thinned area had 22% of BA removed in first thinning; heavier-thinner area had 35% of BA removed. Second thinning rate not known, but was light in the former portion and heavier in the latter. The clearcut harvest retained 18 tpa with mean diameter 63 cm.</p> <p>Reserve trees had a 93% survival rate after 12 yr.; most dead trees had been windthrown. Seedling density (99% Douglas-fir) was somewhat clumped, but 98% of 5x5 m grid cells had at least one conifer seedling. Both seedling density and seedling size within the drip line of reserved tree crowns were less than in the best of the area. In the half of the study plot that had been twice lightly thinned, only 14% of the seedlings were >0.5 m tall; however, 41% of the seedlings were >0.5 m in the block that had been thinned more heavily. There was no difference between the thinning blocks in the ages of seedlings <0.5 m tall (mean age 5 yr.)</p> <p>More shrub clumps present in heavily-thinned area (1.8% of the area) than in the lightly-thinned area (0.2% of the area). Many conifer seedlings were established in the heavily thinned block before the shrub layer was released. Thus, although the heavier thinning before harvest apparently increased shrub cover, the overall effect on seedling stocking was quite small.</p> <p>This example of clearcutting with reserve trees resulted in reasonable survival of the overstory trees and adequate stocking but slow growth rates in the naturally regenerated Douglas-fir. Heavier thinning before harvest was associated with more advance regeneration, more shrub cover, and less windthrow of the reserved trees than in the more lightly thinned block. If an abundance of tree species other than Douglas-fir was desired on this site, interplanting would be required.</p>
50	<p>Busing, R.T., Garman, S.L. 2002. Promoting old-growth characteristics and long-term wood production in Douglas-fir forests. For. Ecol. And Manage. 160:161-175.</p> <p>3 – Not Relevant to Jackson WHMP</p>
27	<p>Carey, A.B., Curtis, R.O. 1996. Conservation of biodiversity: a useful paradigm for forest ecosystem management. Wildl. Soc. Bull. 24(4):610-620.</p> <p>1 - Very Relevant to Jackson WHMP</p> <p>Proposes stages of forest ecosystem development in the Western Hemlock zone:</p> <ul style="list-style-type: none"> Ecosystem initiation Competitive exclusion Understory reinitiation Developed understory Botanically diverse

	<p>Niche diversification Fully functional (managed) Old-growth</p> <p>Compares them with Brown (1985) stages, e.g. Competitive exclusion is similar to closed sapling-pole-sawtimber, and Developed understory is similar to large sawtimber. Carey's descriptions are useful because they describe benefits to wildlife in addition to describing canopy species size/density. He proposes biodiversity treatments for each stage, including variable density thinning with and without CWD and snag augmentation.</p> <p>Management foundations of the biodiversity pathway (sounds very zen-like):</p> <ol style="list-style-type: none"> 1. Conserve biological legacies during harvest and regeneration, including soil organic matter, litter, CWD, snags, forbs, shrubs, mycorrhizal fungi. 2. Plant Douglas-fir at wide spacing; provide for natural or artificial regen of hemlock, red cedar, grand fir, western white pine. Concurrent regeneration of red alder, bigleaf maple, evergreen hardwoods. 3. Minimize area and time in the competitive exclusion stage through PCT and VDT (heavier than conventional commercial thinning). 4. Ensure diversity and niche diversification in later stages through subsequent thinnings with CWD augmentation. 5. Use extended rotations (80-130 yrs). <p>Minimize site prep to reduce invasion by excessive red alder. Control dense shrub layers as needed to secure conifer establishment; in closed-canopy second growth conifer stands, use biodiversity thinnings to maintain or restore diversity.</p> <p>Suggests using 2+ densities in the initial VDT. E.g., retain 309 tpa and 185 tpa in a 2:1 ratio on a 0.2 ha scale in a 30- to 50-year-old stand of 10- to 50-cm dbh trees.</p> <p>Suggests 2 additional VDTs to leave CWD to meet target of 15% cover on the forest floor, maintain understory. CWD size range 10 to 100-cm dbh..</p> <p>Suggests the biodiversity thinnings will produce approximately the same long-term wood production resulting from conventional rotation length, but cost is the reduction in present net value associated with extended rotations.</p>
52	<p>Carey, A.B., Johnson, M.L.. 1995. Small mammals in managed, naturally young, and old-growth forests. <i>Ecol. Applic.</i> 5(2):336-352. 2 – Somewhat Relevant to Jackson WHMP</p> <p>Compared small mammal communities in natural old-growth stands to managed even-aged and uneven-aged stands in Olympic Peninsula. While small mammal abundance and productivity for most species were greatest in natural old-growth, all spp abundance in managed stands as well. Abundance of small mammals in uneven-aged managed stands tended to be intermediate between natural old-growth and young even-aged stands.</p> <p>CWD and understory shrub layer key variables affecting small mammal abundance. Could be maintained or enhanced by partial cutting.</p>
318	<p>Carey, A.B., Kershner, J., Biswell, B., Dominguez de Toledo, L. 1999. Ecological scale and forest development: squirrels, dietary fungi, and vascular plants in managed and unmanaged forests. <i>Wildl. Monog.</i> 142:1-71. 1 - Very Relevant to Jackson WHMP</p> <p>Field study of northern flying squirrel and Townsend's chipmunk habitat variables in managed and natural stands in SW OR.</p>

	<p>4 factors (crown-class differentiation, canopy stratification, understory development and decadence (snags and CWD) accounted for 63% of variance in vegetation structure.</p> <p>Of all the habitat elements measured, CWD proved to be the best predictor of the realized habitat space, activity and carrying capacity of flying squirrels, and carrying capacity for chipmunks. Crown-class differentiation was a major dimension of the realized habitat of chipmunks and the most important predictor of chipmunk abundance. Crown-class differentiation is perhaps the factor forest development most amenable to management: (1) species comp can be determined managerially at stand initiation by legacy retention, planting and PCT, (2) management of stem density and growth rates is well founded, and (3) spacing can be varied tree to tree or patch to patch within stands.</p> <p>"It seems that suppression mortality in conifers does not contribute significantly to the function of standing decadent trees in either provision of cavities or gap formation."</p> <p>Carefully timed VDT could accelerate the 1st 3 characteristics. Spatial pattern is important. Traditional light CT will not move a stand out of competitive exclusion and will not increase habitat breadth. Heavy thinning with even spacing can cause stands to become drier, promote shrub brushfields, disrupt mycorrhizal links and increase windthrow.. VDT on a 0.1-0.5 ha scale that removes subordinate or codominant trees appears to have potential for increasing crown-class differentiation, canopy stratification, understory and habitat breadth. Determining the number of trees to remove can be based on RD; suggests that maintaining RD of 0.5 and 0.35 in a ratio of 2:1 over the stand might work. Hagar et al (1996) recommended VDT with RD of 0.2 - 0.7. Actual choice of RD should entail consideration of risk of windthrow, potential for creation of brushfields, silvics of the spp being managed and site condition. Avoid competitive exclusion phase--Keep canopy open but avoid disrupting connectivity among tree crowns.</p> <p>VDDT computer simulations: After PCT to 740 tpH (300 tpa). Traditional CT allowe quick (ca. 10 yr) canopy closure and return to competitive exclusion. VDT at 30, 50 and 70 yrs and retaining stand-level densities of 247, 123, and 90 tph, produced more wood and enhanced biodiversity; targets were met in <50% of the time required with no management.</p> <p>Manage decadence. >10-15% cover of CWD recommended.</p>
272	<p>Carey, A.B., Wilson, S.M. 2001. Induced spatial heterogeneity in forest canopies: responses of small mammals. <i>J. Wildl. Manage.</i> 65(4):1014-1027.</p> <p>2 - Somewhat Relevant to Jackson WHMP</p> <p>Tests hypothesis that creating a mosaic of interspersed patches of different densities of canopy trees in second-growth Douglas-fir forest would enhance biodiversity. 3 yrs post-treatment, understory species richness and herb cover had increased with variable density thinning. In sufficient time for tree layers to respond.</p> <p>Deer mouse, creeping voles and vagrant shrews populations increased, and no forest-floor small mammals decreased following VDT.</p> <p>Recommends VDT with long rotations, legacy retention, management for snags and CWD for managed Douglas-fir forests.</p>
317	<p>Carey, A.B. 2005. Active intentional management (AIM) for biodiversity and other forest values. In Peterson, C.D., Maguire, D.A., eds. <i>Balancing ecosystem values: innovative experiments for sustainable forestry</i>. Gen. Tech. Rep. PNW-GTR-635. Portland, OR: USDA Forest Service, Pac. NW Res. Stn. P. 227-234.</p> <p>2 - Somewhat Relevant to Jackson WHMP</p> <p>Review article. Mentions comparative studies, experimental studies and computer simulations.</p> <p>2 VDT experiments in accelerating development of biocomplexity (high plant spp diversity, spatial heterogeneity in the understory, vertical foliage diversity) by manipulation 2nd-growth forest canopies similar to that of old growth. Maps of natural mosaics revealed 0.1 - 0.5 ha</p>

	<p>patches with a 2:1 ratio of closed to open canopy. VDT produces mosaic stands</p> <p>Also note legacy stands (originated after clearcutting, but retained scattered large live trees, large dead trees, tall stumps and large CWD. Legacy retention can be used with even-age or uneven-age systems.</p> <p>Experimental results provided for fungi, vascular plants, small mammals and wintering birds.</p> <p>Modeling results provided. "Simply protecting second-growth forest caused the landscape to go through waves of forest development. Initially a substantial ecological crunch occurred because of degraded watersheds and oversimplified stands; a long time (200 years) was required for these stands to achieve an old-growth-like condition." Timber management produced a landscape inhospitable to >20 vertebrate spp; timber management with riparian reserves per federal guidelines produced narrow, well separated strip of late-seral forest, unlikely to function fully as late-seral forest; but biodiversity management produced significant ecological benefits. Costs surprisingly low - only a 15% loss in net present value vs. maximizing timber extraction.. This became a 6% decrease in NPV with required riparian protection.</p>
258	<p>Chambers, C.L., McComb, W.C. 1997. Effects of silvicultural treatments on wintering bird communities in the Oregon Coast Range. NW Science 71(4):298-304.</p> <p>2 - Somewhat Relevant to Jackson WHMP</p> <p>Field study of abundance of resident birds following 3 silvicultural treatments in Oregon Coast Range:</p> <ul style="list-style-type: none"> **modified clearcut (1.2 green trees/ha retained) **small-patch group-selection cut (1/3 volume removed in 0.2-ha circular patches) **two-story cut (3/4 volume removed with 20 - 30 tph green trees retained scattered uniformly through the stand) **uncut control stands <p>Total bird abundance highest in small-patch stands, lowest in modified clearcuts.</p> <p>Spp richness highest in small-patch stands, lowest in control and clearcut stands.</p> <p>Small-patch group-selection treatment retained structural and compositional complexity of vegetation, and provided habitat for more individuals than two-story or clearcut treatments. However, two-story and modified clearcuts with snags, logs, large trees provided habitat for several wintering bird spp.</p> <p>Spp responded variously to the treatments, but in general treatments that retain structural and compositional vegetation complexity, or that develop late-successional characteristics more quickly, may be used by more bird spp than traditional clearcut treatments.</p>
300	<p>Chambers, C.L., McComb, W.C., Tappeiner II, J.C. 1999. Breeding bird responses to three silvicultural treatments in the Oregon Coast Range. Ecol. Appl. 4(1):171-185.</p> <p>2 - Somewhat Relevant to Jackson WHMP</p> <p>Field study assessed bird response to 3 silvicultural treatments in 80-120 yo Douglas-fir/grand fir stands:</p> <ul style="list-style-type: none"> **small-patch group selection treatment representing low-intensity disturbance. 33% of volume removed in 0.2 ha patches **two-story treatment, representing moderate to high-intensity disturbance. 75% of volume removed, retaining 20-30 tph scattered uniformly throughout stand **modified clearcut. 1.2 green trees/ha retained. **control stands <p>Bird species composition in small-patch group selection most similar to control stands. Two-story treatment was more similar to the modified clearcut treatment.</p> <p>10 bird spp remained abundant following small-patch group selection treatment. They declined in abundance in modified clearcuts and two-story treatment. The species included 4</p>

	<p>neotropical migrant species and 5 spp with restricted geographic ranges and habitat associations.</p> <p>9 spp increased in response to moderate and/or high-intensity disturbances, including a larger proportion of species that were habitat generalists.</p> <p>Low- intensity disturbances most effective in retaining bird spp associated with mature forest. High-intensity disturbances (two-story and modified clearcut) greatly altered bird community composition.</p>
160	<p>Corn, J.G., Raphael, M.G. 1992. Habitat characteristics of marten subnivean access sites. <i>J. Wildl. Manage.</i> 56:442-448.</p> <p>3 - Not Relevant to Jackson WHMP</p> <p>Describes the importance of snags, stumps and logs in providing denning habitat in the central Rocky Mountains.</p>
191	<p>Creighton, J.H. 2000. Controlling black bear damage to conifer stands: does the supplemental feeding program work? <i>Forest Stewardship Notes</i> 9(2):9-10.</p> <p>2 - Somewhat Relevant to Jackson WHMP</p> <p>Discussion of usefulness of supplemental feeding to control damage to young conifer stands.</p>
248	<p>Curtis, R.O. 1997. The role of extended rotations. IN: Kohm, K., Franklin, J., eds. <i>Creating a forestry for the 21st century</i>. Washington DC: Island Press, pp.165-170.</p> <p>3 - Not Relevant to Jackson WHMP</p> <p>Extended rotations beyond the scope of the WHMP's forest practices</p>
117	<p>Debell, D.S. and Turpin, T.C. 1989. Control of red alder by cutting. USDA Forest Service. Pacific Northwest Res. Station. Research Paper PNW-RP-414.</p> <p>2 - Somewhat Relevant to Jackson WHMP</p> <p>Best to cut alder in June or July to ensure that stump dies and avoid stump sprouts. Easier to kill older trees (6 to 10 years old) than younger trees (4 years old).</p> <p>Note earlier DNR study (1984). August cutting recommended in addition to June-July.</p>
251	<p>DeBell, D.S., Curtis, R.O., Harrington, C.A., Tappeiner, J.C.. 1997. Shaping stand development through silviculture practices. In: Kohm, K, Franklin, J., eds. <i>Creating a forestry for the 21st century</i>. Washington DC: Island Press., pp. 141-149.</p> <p>2 - Somewhat Relevant to Jackson WHMP</p> <p>Useful recommendations for managing young stands.</p>
79	<p>Franklin, J., Spies, T.A., Van Pelt, R. (and others). 2002. Disturbances and structural development of natural forest ecosystems with silvicultural implications, using Douglas-fir forests as an example. <i>Forest Ecol. And Manage.</i> 155:399-423.</p> <p>3 - Not Relevant to Jackson WHMP</p> <p>Focus on larger-scale management.</p>
18	<p>Franklin, J.F., Berg, D.R., Carey, A.B., Hardt, R.A. 2006. Old-growth conifer forests in Restoring the Pacific Northwest. Dean Apostol & Marcia Sinclair, eds., <i>Society for Ecological Restoration International</i>. Island Press: Washington DC. Pp. 97-121.</p> <p>1 - Very Relevant to Jackson WHMP</p> <p>"How can younger forests be restored through active management to a state that provides similar functions and services as natural old growth?"</p> <p>Recommends: Develop a landscape-level plan. Not all younger forest stands need to be treated--consider them as part of a larger mosaic of future stand conditions. Emulate a</p>

	reference old growth stand in the same area, consider variable density thinning, preserve old growth legacies (snags, CWD, decadent live trees), identify the role of shade-tolerant conifers and hardwoods in the desired future stand condition.
262	<p>Garman, S.L., Cissel, J.H., Mayo, J.H. 2003. Accelerating development late-successional conditions in young managed Douglas-fir stands: a simulation study. Gen. Tech. Rep. PNW-GTR-557. Portland, OR. Pac. NW Res. Stn. USDA Forest Service. 57 pp.</p> <p>1 - Very Relevant to Jackson WHMP</p> <p>Simulation study for young Douglas-fir stands in Central Cascades in west-central OR. Used ZELIG.PNW gap model to evaluate effects of thinning treatments on the development of late-successional features and timber volume.</p> <p>64 treatments simulated for 4 rotation intervals (260, 180, 100 and 80 yrs) starting with a 40 yo managed stand. All rotation strategies included creation of 10 snags per hectare >50 cm dbh from live stems and a mixed-species underplanting. For all rotation strategies, experiments consisted of up to 3 entries and 4 thinning densities. First entry was generally thinning from below to accelerate growth of large boles. Subsequent entries thinned proportionally with an upper diameter limit of 60 cm to reduce stem density while preserving the existing species' size-class distributions.</p> <p>The time required for 5 late-successional attributes (from Franklin & Spies 1991) to reach defined threshold values, and timber volume were recorded for each treatment.</p> <p>Late-successional attributes:</p> <ul style="list-style-type: none"> **canopy height diversity index (CHDI), 8.0 **density of boles >100cm dbh, 10/ha. **density of shade-tolerant spp >49cm dbh, 10/ha. **density of snags >50 cm dbh and >5m tall, 10 /ha **log mass >10 cm large end 3- megagm/ha. <p>Results:</p> <p>2 general thinning strategies promoted late-successional attributes. Thin to create open canopy at age 40 by removing 80% of original density), intensively thin at age 60 (to increase growing space in the now-densely stocked tree understory), limited or no thinning in last entry at age 80 (preserves existing vertical structure and spp diversity) Retain 136 tp-99 tph-186 tph was one such scenario; 136-99-retain all was another--both achieved late-successional criteria by age 117-120 yrs..</p> <p>Alternatively retain more than 40% of original overstory density at 40 yr and thin to 99 tph at 60 yr, and 186 tph in 3rd entry. Compared to not all thinning at all, these thinning strategies accelerated the development of late-successional criteria by about 100 yrs. These thinning strategies limited recruitment rate of dead wood and artificial snag and log-creation was required to reach thresholds.</p> <p>Thus, creating a relatively sparse overstory and managing the tree understory to optimize vertical stratification were key to producing late-successional stand structure. Different thinning regimes achieved the desired result.</p> <p>Decisions of how to implement these strategies must consider likelihood of windthrow. Also consider desired long-term stand conditions. Rapid development of an attribute will not necessarily produce the highest levels of the attribute over the entire rotation. E.g. relatively lower densities of shade-tolerant stems, lower Douglas-fir basal area, lower habitat diversity and fewer snags and logs over the rotation may accompany the fast attainment of late-successional characteristics. Recommended approach uses a variety of treatments with multiple goals.</p>

25	<p>Gray, A.N., Spies, T.A. 1996. Gap size, within-gap position and canopy structure effects on conifer seedling establishment. <i>J. Ecology</i> 84:635-645.</p> <p>1 - Very Relevant to Jackson WHMP</p> <p>Portions of large gaps with direct exposure to the sun had relatively low seedling establishment, particularly for Hemlock. All species were most abundant in the shaded portions of gaps.</p> <p>An increase in gap size corresponded to an increase in seedling size, being the greatest at gap centers.</p> <p>Douglas fir seedling growth was relatively low except in the largest gaps. Hemlock growth increased dramatically with gap size, and silver fir responded the least to gap size.</p> <p>Created gaps may help to accelerate the development of multiple canopy layers.</p> <p>Seedling density appears better related to gap age than to gap size.</p> <p>Both Hemlock and Silver fir can survive for many decades with little growth in shaded forests, and resume growth following a disturbance and concomitant increase in light levels.</p> <p>Contrary to common opinion, Douglas fir can germinate in shade or become established on intact forest floor.</p>
26	<p>Gray, A.N., Spies, T.A. 1997. Microsite controls on tree seedling establishment in conifer forest canopy gaps. <i>Ecology</i> 78(8):2458-2473.</p> <p>1 - Very Relevant to Jackson WHMP</p> <p>Species composition within gaps is likely determined by more than size and shape of the gap; fine scale environmental factors may also be important.</p> <p>Gap sizes were determined by gap diameter:tree height ratios, and were classified as 0.2, 0.4, 0.6 & 1.0</p> <p>Douglas-fir reproduces best on mineral soil in high-light conditions. Hemlock is shade tolerant, but appears to be so sensitive to competition from other understory vegetation while in the seedling stage that successful regeneration is usually limited to growing on decaying Douglas-fir logs.</p> <p>Silver fir is also shade tolerant, but is sensitive to both overstory and understory canopy density.</p> <p>*** Many gaps were found to be devoid of tree saplings more than 50 years after gap formation.</p> <p>For seedling establishment, gap size was marginally significant.</p> <p>Silver fir and Hemlock seedling establishment was greater in the 0.2 and 0.4 gaps than in controls and 1.0 gaps.</p> <p>Hemlock establishment in the 1.0 gaps were significantly lower than the other species.</p> <p>Seedling size increased with gap size.</p> <p>Particularly for silver fir, seedling establishment in the 1.0 gaps was greatest in 90% shade.</p> <p>Seedling survival for both Douglas-fir and hemlock was highest on decayed wood.</p> <p>Douglas fir tended to survive best in shady portions of the sunniest gap area (i.e. north edge) and in the more open portions of the smaller, darker gaps (i.e. south edge).</p> <p>The advantage that hemlock incurs from growing on decaying wood appears to decrease with gap size.</p>
45	<p>Gray, A.N.. 2000. Adaptive ecosystem management in the Pacific Northwest: a case study from coastal Oregon. <i>Cons. Ecol.</i> 4(2):6.</p> <p>3 - Not Relevant to Jackson WHMP</p>
198	<p>Grialou, J.A., West, S.D., Wilkins, R.N. 1999. The effects of forest clearcut harvesting and thinning on terrestrial salamanders. <i>J. Wildl. Manage.</i> 00(0):000-000.</p>

	May have been published in J. Wildl. Manage. Could not find this reference.
190	<p>Gyug, L.W. and S.P. Bennett. 1995. Bird Use of Wildlife Tree Patches 25 Years After Clearcutting. In: Bradford, P., T. Manning and B. l'Anson eds. Wildlife Tree/ Stand-Level Biodiversity Workshop Proceedings. Victoria, B.C. October 1995. 15-33.</p> <p>1 - Very Relevant to Jackson WHMP Study conducted in South-Central B.C.</p> <p>Wildlife tree patches were designated as "no-work" zones where snags did not have to be felled for worker safety.</p> <p>In one harvest area, 7% of the 160 ha harvest area was reserved in 12 seed tree patches, with a mean patch size of 0.9 ha (range 0.3 - 1.5 ha); mean inter-patch distance to neighbor was 203m.</p> <p>In another harvest area or 1000 ha, 29 seed tree patches were left (10% of harvest area). Mean patch size was 3.6 ha (range 1.6 - 18.9 ha). Mean distance between patches was 201m. Most patches were small (median 2.3 ha).</p> <p>Owls and woodpeckers were sampled in the harvest units 25 to 29 years post-harvest. No species of either were detected in clearcuts, some were found in forest patches, and all were found in the neighboring forest.</p> <p>The Pileated was absent from the patch areas and clearcuts.</p> <p>Hairy woodpecker, Northern flicker and red-naped sapsucker were found in the patch environments.</p> <p>Tree species, diameter and decay class were much more significant in determining woodpecker use of individual wildlife trees than the habitat.</p> <p>A majority of nests were found in snags greater than 75 cm dbh.</p> <p>Authors felt that wildlife tree patches were quite effective at mitigating the effects of clearcutting on many species.</p> <p>Only one cavity-nesting bird was found in the harvest units without reserve patches.</p>
244	<p>Hagar, J. 2006. Key elements of stand structure for wildlife in Pacific Northwest conifer forests. In Harrington, T.B., G.E. Nicholas, tech. eds. Managing for wildlife habitat in west-side production forests. Gen. Tech. Rep. PNW-GTR-695. Portland, OR:USDA Forest Service, Pac. NW Res. Stn. Pp.35-48.</p> <p>1 - Very Relevant to Jackson WHMP Review article discusses key features:</p> <p>Large trees, e.g. wolf trees, remnant old growth trees. If evenly dispersed, large trees in otherwise unsuitable (i.e.harvested) areas can facilitate movement of forest interior spp. Options for recruiting, developing and maintaining large trees include retaining green trees at harvest, and growing them at reduced stand density to provide growing space for larger limbs and deeper crowns.</p> <p>Large dead wood. Size and decay stage matter. Habitat value increases with diameter, and a diversity of decay stages of snags and logs. Avg. diameter of snags used by all wildlife spp for nesting or denning exceeds 50 cm. Chipmunks selected logs that have larger avg diameters than randomly available wood to use at travel paths. Den sites for large animals (e.g. bear) are limited to logs of >80 cm.</p> <p>Current guidelines for augmenting volumes of woody debris in managed forests may be</p>

	<p>inadequate to maintain populations of all associated spp. (Rose et al 2001, Wilhere 2003). At least 10 snags >25 cm dbh per hectare recommended, (Hayes and Hagar 2002, Mellen et al 2006). Avg. diameter of snags used by cavity-using spp is >56 cm (Mellen et al 2006).</p> <p>Management strategy for spp associated with dead wood should ensure spatial and temporal continuity of habitat.</p> <p>**Retain existing large snags and logs during timber harvest</p> <p>**Plan for future recruitment of dead wood. Retained trees can be clumped in patches for safety and operational ease.</p> <p>**Use advisory tools, DecAID (Mellen et al 2006) and Coarse Wood Dynamics model (Mellen and Ager 2002) to plan dead wood management.</p> <p>Floristic diversity, in particular the presence of shrubs and hardwood trees, especially important for wildlife diversity. Literature shows consistent patterns of positive correlations b/n birds and abundance and distribution of hardwoods in conifer forests.</p> <p>"Hardwoods may be preferred by many species [of cavity-nesting birds and mammals] because wood properties and decay patterns often result in softened heartwood that is easily excavated, while the sapwood remains unaffected by decay...In contrast, sapwood of Douglas-fir snags often decays by the time heartwood is sufficiently softened for cavity excavation...Because of these differences, hardwoods can provide suitable cavity sites at relatively smaller diameters than conifers (Bunnell et al. 1999).</p> <p>Management of hardwoods should begin early in stand development. Controlling density at an early age, before canopy closure, can help to maintain diverse stand structure throughout the life of a stand (Tappeiner et al. 2002). Although shrubs may dominate early succession, it is unlikely that clear-cutting can be used to immediately create quality habitat for shrub-associated wildlife spp.</p> <p>Commercial thinning has the potential to increase habitat value for shrub-associated wildlife. (citations) Cover and productivity of shrub understory may respond positively to thinning. Variable density thinning may further enhance habitat by increasing spatial heterogeneity. Leave trees may be selected on the basis of characteristics such as cavities, large limbs. Etc. rather than spacing.</p> <p>Sites for shrubs and hardwoods minimize impacts of timber production may include seeps, wet depressions, small wetlands, riparian areas, road edges, landings, root rot pockets. Intentionally-managed canopy gaps could serve as sites for large trees, snags and floristic diversity.</p>
128	<p>Hagar, J.C., McComb, W.C., Emmingham, W.H. 1996. Bird communities in commercially thinned and unthinned Douglas-fir stands of western Oregon. <i>Wildl. Soc. Bull</i> 24(2):353-366.</p> <p>2 - Somewhat Relevant to Jackson WHMP</p> <p>Study compared abundance and diversity of breeding and winter birds between commercially thinned and unthinned second-growth Douglas-fir stands in the Oregon Coast Ranges.</p> <p>64 habitat variables sampled or derived from data: e.g. distance to streams, distance to patch edge, patch size, height and diameter of tree layer, basal area of conifers, hardwood, snags, snag size, woody vegetation height, percent shrub and tree cover, and others.</p> <p>Abundance of many breeding birds consistently greater in thinned stands: (Hammonds's flycatchers, hairy woodpeckers, red-breasted nuthatches, dark-eyed juncos, warbling vireos and evening grosbeaks)</p> <p>Abundance of few other species consistently greater in unthinned stands (Pacific-slope flycatchers).</p>

	<p>Some species were inconsistent in thinned or unthinned stands between seasons, years, or regions (brown creeper, western tanager, winter wren, golden-crowned kinglets, gray jays, black-throated gray warblers, and others).</p> <p>Bird species richness correlated with structural features: habitat patchiness and densities of hardwoods, snags and conifers. In general, enhance structural features associated with richness by increasing size and abundance of hardwoods, conifers and snags, and providing shrub cover.</p> <p>Management recommendations: Commercial thinning for Hammond's flycatchers, western tanagers because these species have declined in abundance.</p> <p>Commercial thinning plus create snags and release hardwoods for other species in decline: chestnut-backed chickadees, warbling vireos, black-throated gray warblers.</p> <p>Thin from below for species associated with old, unmanaged forests (e.g. Hammond's flycatcher, red-breasted nuthatch). Recommended relative density between 0.2 and 0.3, (i.e. only short periods of crown closure allowed). Development of shrub cover associated with Wilson's warblers, Swainson's thrushes and warbling vireos. Low tree stem density may favor Hammond' flycatchers, hairy woodpeckers, and dark-eyed juncos.</p> <p>Higher relative densities of trees (>4.0+) benefits golden-crowned kinglets and Pacific-slope flycatchers. Black-throated gray warblers may benefit from denser stands if hardwoods also present. (Note: competition mortality of tree layer was found at RD>0.55)</p> <p>Recommend variable densities across a stand (0.2 - 0.7) for bird species richness, as follows: unthinned strips or patches (approx. 8ha per 40 ha of thinning, to include birds' territories, could be left adjacent or within thinned stands.</p>
217	<p>Halpern, C., McKenzie, D., Evans, S., Saracco, J., Maguire, D, Halaj, J. 2005. Vegetation responses to varying levels and patterns of overstory retention:early results of the DEMO experiment. In. Peterson, C.E., Macuire, D.A., editors. Balancing ecosystem values: innovative experiments for sustainable forestry. Proceedings of a conference. Gen.Tech. Rep. PNW-GTR-635. USDA Forest Service. Pp. 357-359.</p> <p>2 - Somewhat Relevant to Jackson WHMP DEMO study early results. See #214 for experimental design. Focus on post-harvest mortality of trees and responses of two groups of understory plants: late-seral herbs nad ground-layer bryophytes.</p> <p>Focus on 5 of the 6 treatments: control, and four treatments that contrast level of retention (40 vs. 15% of original basal area) and appregated vs. dispersed distribution.</p> <p>Tree mortality: cumulative mortality significantly greater at 15% than at 40% retention. At both levels of retention, aggregation of trees significantly reduced mortaltiy. Mortality of co-dominants greater at lower levels of retention, especially in dispersed treatments. Suppressed trees had high mortality in dispersed than in aggregated treatments. Wind damage particularly common in the 15% dispersed treatment.</p> <ol style="list-style-type: none"> 1. Short-term, forest aggregates of 1-ha are fairly stable 2. At low retention levels, dispersed patterns susceptible to logging and wind damage, leading to increased mortality, even among co-doms. <p>Understory:</p>

	<p>Declines in spp frequency and richness, and changes in spp comp significantly greater at lower level of retention. Pattern of retention had little effect on understory response. This result attributed to extremes in response within the aggregated treatments: post-harvest changes small within the aggregates, but declines in adjacent harvest areas were large and generally greater than those in dispersed treatments. Late-seral herbs particularly sensitive to these effects, more frequent extirpations from harvested portions of aggregated treatments. These initial responses to harvest consistent with patterns of ground disturbance and slash accumulation which varied among the treatments. As effects of disturbance diminish over time, expect that variation in overstory will play more important role in understory recovery.</p> <p>Higher retention reduced wind throw and loss of late-seral herbaceous spp. Responses to pattern of retention were mixed: tree mortality reduced in aggregated treatments, but benefit of aggregated retention for understory plants limited to forest aggregates. In adjacent harvest areas, spp showed greater declines than in dispersed treatment areas. Forest aggregates serve as refugia for plant spp that are sensitive to disturbance or require deep shade or moist substrates. Long-term may be sources of dispersal to adjacent harvest areas.</p> <p>These functions may be compromised by edge effects, but suggest that patches of 1-ha sufficiently large to maintain viable populations of most spp.</p>
215	<p>Halpern, C.B., Evans, S.A., Nelson, C.R., McKenzie, D., Liguori, D.A., Hibbs, D.E., Halaj, M.G. 1999. Response of forest vegetation to varying levels and patterns of green-tree retention: an overview of a long-term experiment. Northwest Sci. 73(special issue):27-44. 2 - Somewhat Relevant to Jackson WHM Part of DEMO study. See #214. Review of retrospective studies and simulation models.</p> <p>Cites North et al (1996) - the only single, short-term study that has evaluated the consequences of dispersed retention for forest understory communities. 16 mo. After harvest, spp composition of a dispersed retention unit resembled that of an adjacent clearcut more than that of an adjacent intact forest, reflecting increase of early successional spp. However, shade-tolerant forest spp more diverse and abundant in the dispersed unit than in the clearcut, suggesting that forest understory taxa may benefit from increased shading and/or reduced disturbance afforded by retained trees.</p> <p>Lists a series of hypotheses, with proposed analytical approaches, related to responses of forest vegetation to different green tree retentions.</p> <p>Separating the effects of logging disturbance from effects of retention (short-term effects vs long-term effects) is an important focus of the research. Short-term responses to treatment likely to be driven by variation in the distribution and intensity of harvest disturbance. Longer-term trends are expected to reflect the effects of contrasting patterns of canopy retention.</p>
216	<p>Halpern, C.B., McKenzie, D., Evans, S.A., Maguire, D.A. 2005. Initial responses of forest understories to varying levels and patterns of green-tree retention. Ecol. Appl. 15:175-195. 2 - Somewhat Relevant to Jackson WHM See #217</p>
213	<p>Halpern, C.B., Spies, T.A. 1995. Plant species diversity in the natural and managed forests of the Pacific Northwest. Ecol. Appl. 5(4):913-934. 2 - Somewhat Relevant to Jackson WHMP Data from permanent plots and chronosequence studies in managed and unmanaged forests of western OR and WA. Describes understory response to harvest. Post-harvest practices alter natural successional processes may influence long-term patterns of diversity and species occurrence.</p> <p>Early succession in old growth Douglas-fir forests suggest that changes in understory diversity</p>

	<p>are fairly short-lived following clearcut and slash burning. Most vascular plant populations recover to original levels prior to canopy closure. Diversity may remain depressed for more than two decades on severely burned sites; some species experience local extinction.</p> <p>Evidence of the effects of post-harvest practices on vascular plant diversity limited by absence of studies in older, managed forests. Chronosequence studies of natural forest stands indicate that, following canopy closure, vascular plant species diversity tends to increase with time, peaking in old growth. Few understory species are restricted to any stage of stand development, but many species differ in their abundance among stages. Most showed greatest abundance in old growth. Temporal changes in levels of resources (shade), changes in spatial distrib. of resources, and species' sensitivity to fire and slow rates of reestablishment may drive these trends in natural stand development.</p> <p>Silvicultural prescriptions that maintain or foster spatial and temporal diversity of resources and environments will be most effective in maintaining plant species diversity. It may be necessary to manage some stands on long rotations (150-300 yr) to maintain understory species with slow recovery rate after disturbance.</p>
266	<p>Hansen, A.J., Garman, S.L., Weigand, J.F., Urban, D.L., McComb, W.C., Raphael, M.G. 1995. Alternative silvicultural regimes in the Pacific Northwest: simulations of ecological and economic effects. <i>Ecol. Appl.</i> 5(3):535-554.</p> <p>2 - Somewhat Relevant to Jackson WHMP</p> <p>New silviculture regimes at the stand level include rotation age and retention level of live trees in harvest units to promote stand structure in managed forest similar to those in natural forests. Concern over reduced wood production.</p> <p>Forest model ZELIG used to simulate long-term responses of ecological and economic variables to 9 retention levels (0, 5, 10, 15, 20, 30, 50 and 150 tph) and 4 rotation lengths (40, 80, 120, 240 yrs). Each scenario run for a 240-yr period. Simulated stands replanted with 988 Douglas-fir seedlings per hectare. Thinned to 543 tph 15 and 30 yr following planting.</p> <p>Simulated stand data linked with regression equations to predict densities of 17 bird species as a function of tree size class distribution.</p> <p>Results:</p> <p>Stand structure under canopy tree retention levels was more similar to pre-treatment natural forest than following clear-cutting.</p> <p>Variation in tree size under intermediate retention levels (e.g. 10 to 30 tph) did not reach the level of the natural forest during the simulation period. Necessary to retain multiple size classes of trees at harvest to produce stand structures typical of natural forest.</p> <p>Tree species composition strongly related to retention level and rotation age. Douglas-fir lost dominance to shade-tolerant species under intermediate retention levels (5 to 30 tph) and longer rotations >120 yr.</p> <p>Wood production decreased with increasing retention level and rotation age, with a notable threshold between retention levels of 0 and 5 tph. Cumulative BA highest under clear-cutting and 40-yr rotation. Cumulative BA didn't change much at retention level >100 tph.</p> <p>Bird species responded individually to retention level and rotation age; most associated with structurally complex, closed-canopy forest. Richness peaked under intermediate retention levels just after harvests, decreased during years 20-40 as canopy closure occurred and open-canopy bird species dropped out, then returned to levels near that of retention = 150 tph thereafter. Bird species richness increased significantly with moderate retention level and long rotations.</p> <p>Retaining 5 tph would appear to best optimize mean bird richness and wood product value.</p>
267	<p>Hansen, A.J., McComb, W.C., Vega, R., Raphael, M.G., Hunter, M. 1995. Bird habitat relationships in natural and managed forests in the west Cascades of Oregon. <i>Ecol. Appl.</i> 5(3):555-569.</p>

	<p>3 - Not Relevant to Jackson WHMP Bird abundance data from several studies.</p> <p>Most forest birds can be placed in 4 guilds in terms of overstory tree canopy use: **open canopy spp (dark-eyed junco, american robin) **open canopy with dispersed large trees (MacGillivray's warbler, Hammond's flycatcher, western tanager) **structurally complex closed-canopy (brown creeper, chestnut-backed chickadee, winter **structurally simple closed-canopy (golden-crowned kinglet, Swainson's thrush)</p>
166	<p>Hargis, C.D., McCullough, D.R. 1984. Winter diet and habitat selection of marten in Yosemite National Park. <i>J. Wildl. Manage.</i> 48:140-146.</p> <p>2 - Somewhat Relevant to Jackson WHMP California study results</p> <p>Recommendation: "The impact of clear-cutting may be reduced by leaving clusters of trees spaced no farther than 50 m apart. Logs and slash should be left for foraging sites, winter dens and subnivean travel routes."</p>
310	<p>Harrington, C.A., Roberts, S.D., Brodie, L.C. 2005. In: Peterson, C.D., Maguire, D.A., eds. <i>Balancing ecosystem values: innovative experiments for sustainable forests</i>. Gen. Tech. Rep. PNW-GTR-635. Portland, OR: USDA Forest Service, Pac. NW Res. Stn. P. 97-106.</p> <p>2 - Somewhat Relevant to Jackson WHMP Olympic Habitat Development Study initiated in 1994, evaluates where management of 35- to 7 y.o. stands could accelerate late-successional characteristics. Variable-density thinning involving complex prescription: Skips = untreated patches and Gaps + stand openings embedded in a thinned matrix. Skips about 0.1 to 0.3 ha and covered 10% of plot area. Skips preserved large snags, with max. 1 skip per about 2.0 ha. Gaps 0.04 to 0.05 ha, covered 15% of the plot area. Used existing root-rot pockets. Matrix covered 75% of treatment area, thinned by removed 25% of basal area, mostly from below.</p> <p>Assessed tree damage, mostly windthrow, 5-yr tree growth, 3-yr vegetation development.</p> <p>Tree growth responded positively to thinning. Understory vegetation responded to thinning with increased cover and number of herb spp in thinned areas and created gaps. Introduced spp most prevalent in the thinned and gap subtreatments vs skips or control plots. All introduced spp were herbaceous except Him. Blackberry. Shrub response slower than herb response and more variable. Shrubs previously present on stands persisted despite damage, and are slowly increasing. Cover of mosses and liverworts greatest in undisturbed areas. Thinning rx was operationally feasible.</p>
245	<p>Harrington, T.B. 2006. Silvicultural guidelines for creating and managing wildlife habitat in westside production forests. In Harrington, T.B., G.E. Nicholas, tech. eds. <i>Managing for wildlife habitat in west-side production forests</i>. Gen. Tech. Rep. PNW-GTR-695. Portland, OR: USDA Forest Service, Pac. NW Res. Stn. Pp. 49-60.</p> <p>1 - Very Relevant to Jackson WHMP Designing New Stands Pre-treatment planning required to identify appropriate treatment intensity, to retain existing structural elements, or provide conditions for development of new structural elements. Specific habitat features that can be retained or created: **forage (mast, browse, or grazing) spp **nest sites **snags and green trees **shrub cover **CWD</p>

	<p>Areas in harvest unit can be designated for wood production, combination of wood production and wildlife habitat, and habitat only, to avoid conflicting treatments.</p> <p>Cites WA DNR (2006) recommendations for snags:</p> <ul style="list-style-type: none"> **Locate snags away from trails, roads, buildings, etc. **Conifer snags last longer than hardwood snags; selected trees should have a stem diameter of at least 14 in to provide nest sites and for increased longevity. **Trees should be topped or girdled at or above the first whorl of branches, at least 14 ft above ground and ideally much higher. Smaller trees or stumps at least 3 ft tall may be useful for some cavity nesters **A jagged top decays faster **Artificial cavities, (6 in deep X 4 in high) accelerate decay in new snags **Large branches (2 ft long or more) provide foraging habitat **Roosting slits (angled upward at least 8 in deep and 8 in wide) are used by bats and some birds <p>Establishing Understory Conifers</p> <p>If goal is to manage understory conifers as a second story for habitat (and ultimately crop trees), recommends relatively low overstory. Overstory density should not exceed 20% of full stocking.</p> <p>Reduction in overstory density can result in excessive conifer regen. Can reduce regen via moderate soil disturbance during timber harvest or a subsequent pre-commercial thinning</p> <p>Promoting Understory Vegetation</p> <p>Thinning combined with moderate soil disturbance creates germination substrates for seedling regen of woody and herbaceous spp. Thinning Douglas-fir stands is followed by increases in seedling germination of salal, vine maple, huckleberry, tanoak, bigleaf maple, red alder, salmonberry, Pacific madrone. However, development of shrub cover and wildlife forage occurs much more rapidly from sprouts, which is the preferred method of regeneration.</p> <p>Thinning intensity and pattern influence spatial distribution of woody debris and soil disturbance. In the DEMO study, depth and cover of debris were greater at the highest thinning intensity and in aggregated vs. dispersed retentions of overstory trees (Halpern and McKenzie 2001).</p> <p>Using thinning to create old-forest structure</p> <ul style="list-style-type: none"> **Retain large trees from previous stand, especially those with large limbs, cavities and rough bark **Retain minor spp including Sitka spruce Engelmann spruce, yew **Create seedbeds for establishment of understory plants, via soil disturbance (e.g. skidding of logs) **Control understory competition when it becomes excessive. A dense understory of shrubs like salal, vine maple, salmonberry, huckleberry or blackberry; hardwoods like bigleaf maple, can interfere with seedling establishment of conifers and otherspp. In these cases, it may be necessary to control shrubs and hardwoods, and plant conifer seedlings to establish a multi-storied stand. **Manage some trees or parts of stands at low density, via thinning around selected trees in order to provide space, maintain large crowns and continue rapid diameter growth. **Use thinning to favor patches of regeneration. Thinning can be concentrated around patches of advanced tree regen to facilitate development of multi-storied stands. **Allocate trees for production of snags and CWD See DecAID guidelines to produce appropriate abundances and sizes of woody debris **Relatively dense overstories favor some herbaceous spp. Maintaining dense patches of overstory trees or excessive conifer regen may retard establishment of a dense shrub cover,
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	<p>and provide sites for late-seral herbaceous plants (Lindh 2005).</p> <p>**Large (>40 in diameter) old (>200 yrs) trees will respond positively to thinning.</p> <p>**Create space for hardwoods. Reduce conifer density around hardwood to maintain full vigorous crowns. Recommends heavy thinning around 0.25 to 0.6-ac patches of hardwoods.</p> <p>Opportunities to do these things occur sporadically in stands, therefore, density will be spatially variable. E.G. if the goal is to grow 30 large trees/ac, the range might be >40 trees in some areas and <10 trees elsewhere, with an avg. of 30 trees over an area of 5 to 10 ac.</p> <p>Information needs for planning stand development:</p> <p>**Sizes, densities and spp comp of large overstory trees and second-story trees needed to produce multi-storied stands.</p> <p>**Stand density or gap size needed to grow understory trees</p> <p>**Sizes and densities of existing snags and CWD</p> <p>**Effects of snow, wind, insects and pathogens on tree mortality and the associated production of snags, logs on the forest floor, and cavities.</p> <p>Tree and stand responses to thinning.</p> <p>At the stand level, thinning reduces competition for light, water and nutrients, thereby increasing the growth of overstory trees and the abundance of understory plants.</p> <p>A major response of trees to thinning is increase in crown size. Tree crown height increases as lower branches survive and height growth continues. As crown length increases, stem diameter increases on the lower part of the stem: the tree's stem becomes more tapered and more resistance to windthrow or stem breakage. An increase in diameter may occur within 3 to 5 yrs. Epicormic branching in Douglas-fir produces fan-like branches using for roosting by birds and rodents.</p> <p>Caveats.</p> <p>Treating stands once with a single heavy thinning might create a dense shrub (or conifer) understory with low diversity. Thinning around hardwoods would then be necessary. Suggests conducting light thinning to begin the process and develop options for future development. E.g. the initial treatment might enable reprod in the understory and begin development of large trees. A 2nd thinning would release the understory trees and provide for continued growth of large trees.</p> <p>Thinning leads quickly to understory density, and conifer regen. Immediate benefits to wildlife. Other old forest attributes, like large cavities, nesting platforms on large limbs, or high abundance of CWD, will take decades to develop.</p>
16	<p>Hartwig, C.L., D.S. Eastman and A.S. Harestad. 2002. Forest age and relative abundance of pileated woodpeckers on southeastern Vancouver Island. In: Laudenslayer, W.F. et al. eds. Proc. Of the Symposium on the Ecology and Management of Dead Wood in Western Forests. PSW-GTR-181. pp. 247-256.</p> <p>2 - Somewhat Relevant to Jackson WHMP</p> <p>PWP did not use managed forests <80 years old that had low densities of large snags & logs.</p>
80	<p>Hayes, J.P., Chan, S.S., Emmingham, W.H. (and others). 1997. Wildlife response to thinning young forests in the Pacific Northwest. J. Forestry 95(8):28-33.</p> <p>2 - Somewhat Relevant to Jackson WHMP</p> <p>Review article on enhancing stand structure in second growth stands.</p> <p>---Promote large live trees. Thinning results in increased diameter growth</p> <p>-- Promote large crowns to provide better habitat for birds, red tree voles.</p> <p>---Thinning in 20- to 50-year-old stands promotes development of large crowns on dominant and codom trees if done relatively early in a stand's development. See Marshall 1992.</p> <p>---Promote large branches. They develop only on widely spaced trees or on trees adjacent to gaps or openings.</p>

	<p>---Deep fissures in the bark, typical of large-diameter Douglas fir. No silvicultural techniques available to accomplish this, but could create desirable habitat.</p> <p>---Promote large snags and down trees. No numbers provided</p> <p>---Multilayered canopies. No specifics</p> <p>---Understory vegetation. Response of understory veg to thinning depends on initial density, species composition, vigor of understory plants before thinning, seed sources and bud banks, thinning intensity, soil disturbance; however, sunlight is the primary factor. Thinning to moderate densities in closed-canopy stands stimulates modest and temporary development of understory veg (e.g. RD 25); heavier thinning or multiple entries favors the establishment and growth of conifer seedlings, shrubs and hardwoods (e.g. RD 20).</p> <p>Timing: Thinning stands before age 15 will encourage wind firmness and large crowns. Thinning dense stands in the stem exclusion stage increases potential for windthrow, although thinning in stages can minimize the problem. Repeated thinning in later stages (age 70 to 100) may lead to stands resembling shelterwood, with understory beneath a few large trees.</p> <p>Relative Density: The actual density of trees relative to the theoretical maximum density possible for the site, on a scale of 0 to 100.</p> <p>At RD>55m suppression mortality happens</p> <p>Stands typically thinned to RD 35 for timber production, and allowed to grow back to RD 55 before final harvest or additional thinning.</p> <p>Thinning to >RD 35 is a light thinning.</p> <p>Thinning to RD 25 or less (heavy thinning) and thinning again when the stand grows to RD 45 promotes understory development and vertical diversity.</p> <p>RD diagram (see supportive link) predicts stands can have about 20 healthy, 50-inch dbh trees per acre; stands at this density are likely to have a rich understory. Stands with 40 50-inch dbh douglas-fir trees per acre are likely to be in poor condition and have little understory; trees at this density will also attain that size relatively slowly. Need empirical evidence to confirm this.</p>
286	<p>Hayes, J.P., Weikel, J.M., Huso, M.M. 2003. Response of birds to thinning young Douglas-fir forests. <i>Ecol. Appl.</i> 13(5):1222-1232.</p> <p>1 - Very Relevant to Jackson WHMP</p> <p>Breeding bird surveys before and five years after thinning stands in western Oregon. 22 species analyzed in this paper. Treatments on 35-45 y.o. Douglas-fir stands:</p> <p>Control = no thinning</p> <p>moderate thinning = relative density of 35, or 240-320 tph</p> <p>heavy thinning = relative density of 20, or 180-22- tph</p> <p>Results: Response of birds to thinning was generally rapid, with patterns for most spp evidence during the 1st yr after thinning. Patterns of response for most spp relatively consistent across years; marked temporal patterns not common.</p> <p>Hutton's vireo and brown creeper - negative response to intensity of thinning</p> <p>Hermit warbler, golden-crowned kinglet, Swainson's thrush, black-throated gray warbler also decreased on thinned stands, but no change relative to thinning intensity.</p> <p>Stellar's jay and varied thrush decreased only in heavily thinned stands.</p> <p>No change: gray jay, chestnut-backed chickadee, winter wren, Wilson's warbler, red-breasted nuthatch</p> <p>Dark-eyed junco and hairy woodpecker increased in moderately thinned and even more in heavily thinned stands. Warbling vireo increased only in heavily thinned stands.</p> <p>American robin, Townsend's solitaire, evening grosbeaks, western tanagers and Hammond's flycatcher all increased in thinned stand but no difference relative to thinning intensity. The solitaire and flycatcher never observed in control stands.</p> <p>Management recommendations: Thinning densely stocked conifer stands in landscapes</p>

	<p>dominated by younger stands enhances habitat suitability for several bird spp, (consistent with findings of Hagar et al 1996, Haveri and Carey 2000), but some unthinned patches (<0.5 ha) and stands should be retained to provide refugia for species that are impacted by thinning. Suggests variable-density thinning with retention of legacy structures and dead wood.</p> <p>Caveats: Results may not be applicable to much more intensive treatments, e.g. shelterwood. Results were 1st 6 yrs post-thinning: response of birds >10 yrs post-thinning need to be studied. Did not study influence of thinning on reproduction or survival, possibly more important indicators of habitat quality than abundance. Possible influence of different adjacent habitats despite generous size of stands (25 - 40 ha).</p> <p>Generalities: Strongest inference can be applied to forests of similar structure in the same region. However, since findings consistent with known natural history of these spp, likely their results applicable to same spp in other coniferous forests of similar structure.</p>
279	<p>Humes, M.L., Hayes, J.P., Collopy, M.W. 1999. Bat activity in thinned, unthinned, and old-growth forests in western Oregon. <i>J. Wildl. Manage.</i>, 63(2):553-561.</p> <p>2 - Somewhat Relevant to Jackson WHM</p> <p>Foraging facilitated by canopy gaps</p>
150	<p>Jones, L., Holyan, J., Ray, S. 1993. Ecology and management of American martens in fragmented habitats of the Pacific Northwest. Progress Report: Fiscal Year 1993. USDA Forest Service Pacific NW Res. Stn., Forestry Sciences Laboratory, Olympia, WA.</p> <p>Marten used the largest trees in the vicinity as resting sites:</p> <ul style="list-style-type: none"> Live trees (44%), avg. 92.1 cm dbh and 35.7 m tall Snags (20%), avg. 81.6 cm dbh, 13.9 m tall Slash pile (% unclear) <p>Natal den sites had attributes similar to resting sites: a large live hemlock near a stream is typical.</p>
149	<p>Jones, L.L.C. 1990. Ecology and management of marten in fragmented habitats of the Pacific northwest. Progress Report: Fiscal Year 1991. USDA Forest Service Pacific NW Res. Stn., Forestry Sciences Laboratory, Olympia, WA.</p> <p>2 - Somewhat Relevant to Jackson WHM</p> <p>The first year of radio-telemetry field work on marten on the white River Ranger District, Mount Baker-Snoqualmie National Forest.</p> <p>Old growth western hemlock/silver fir forest use disproportionately, in proximity to streams or rivers, year-round.</p> <p>Home range size averaged 805 ha for females, 1571 ha for males.</p> <p>Resting sites:</p> <p>Live trees (45%), used in accordance with their availability. Avg. 97 cm dbh, 32.3 m tall for western hemlock, Douglas-fir slightly larger and taller. Live hemlocks had numerous cavities originating as dead branches that had rotten into the bole, or from scars in the bark. Witch's brooms and heart rot cavities, broken-topped trees were occupied by martens</p> <p>Snags (23%) in decay class 4, with most of the bark missing, major branches gone, and soft, or hollow interiors. Avg. 81 cm dbh and 13.3 m tall</p> <p>Log or slash piles (10%)</p> <p>2 natal dens found in large live hemlock trees.</p>

133	<p>Jones, L.L.C. 1991. Ecology and management of marten in fragmented habitats of the Pacific northwest. Progress Report: Fiscal Year 1991. USDA Forest Service Pacific NW Res. Stn., Forestry Sciences Laboratory, Olympia, WA.</p> <p>2 - Somewhat Relevant to Jackson WHMP</p> <p>Study involving radio-telemetry and camera monitoring in western Washington sites.</p> <p>Martens used old growth forests disproportionately, and used clearcuts less frequently than available in their home ranges. (Note, the study area lacked mature second-growth forests, 20 to 80 years old). Martens were usually located near streams.</p> <p>Resting sites included live trees (42%, of which 70% were western hemlock). Snags accounted for 23% of the resting sites. Manmade slash piles accounted for 11%. Large canopy trees were used according to their availability, although western hemlock was utilized more than Pacific silver fir. Average dbh of live tree resting sites was 100 cm. Average dbh for snags was 81 cm.</p> <p>Natal dens were similar to typical resting sites: large-diameter live trees (usually western hemlock) or snags, near water.</p>
209	<p>Keeton, W.S., Franklin, J.F. 2005. Do remnant old-growth trees accelerate rates of succession in mature Douglas-fir forests? Ecol. Monog. 75(1):103-118.</p> <p>2 - Somewhat Relevant to Jackson WHMP</p> <p>Remnant old-growth trees persisting in mature Douglas-fir forests in southern Washington Cascades are discussed. Hypothesis: Remnant old-growth western hemlock and western red cedar trees enhance the reestablishment of shade-tolerant conifers by increasing the availability of seed.</p> <p>Two study areas had an unfragmented mature forest cover that was regenerated naturally following wildfire. Sites with remnant hemlock and cedar had high densities of conspecific seedlings. Shade-tolerant conifers are likely to reestablish faster at sites with remnant seed trees, but canopy disturbances are probably necessary for subsequent height growth.</p>
282	<p>Kerns, B.K., Alexander, S.J., Bailey, J.D. 2004. Huckleberry abundance, stand conditions, and use in western Oregon: evaluating the role of forest management. Econ. Botany 58(4):668-678.</p> <p>Analysis of data from old growth, young thinned, young unthinned Douglas-fir stands in western OR. All young stands 50 - 120 yrs old, with operational thinnings 10 - 25 yrs before this study. Old growth stands >200 yrs old.</p> <p><i>Vaccinium ovatum</i>, <i>V. parvifolium</i>, <i>V. membranaceum</i> studied. Results variable. Site history and conditions, such as substrate availability, apparently very important.</p> <p><i>Ovatum</i> associated with old growth and unthinned stands; stand thinning may not increase frequency or density. Slow-growing, shade tolerant sp. That lacks rhizomatous growth and might not be able to spread following stand thinning.</p> <p><i>Parvifolium</i> significantly more dense in young thinned stands than in young unthinned stands. Density also related to intensity of thinning.</p> <p><i>Membranaceum</i> associated with old growth stands, but berry production tends to decline in closed-canopy forests.</p>
239	<p>Klinka, K., H.Y.H. Chen, Q. Wang and L. de Montigny. 1996. Forest Canopies and Their Influence on Understory Vegetation in Early-Seral Stands on West Vancouver Island. Northwest Sci. 70: 193-200.</p> <p>1 - Very Relevant to Jackson WHMP</p> <p>Cover of salmonberry is strongly related to canopy cover, but not canopy species.</p>

	<p>While canopy cover has a strong influence on the understory vegetation, other factors including site quality, pre-disturbance vegetation, and type of disturbance have a greater influence on the understory composition.</p> <p>Both salmonberry and salal increased in the understory as the canopy cover decreased, and both were shaded out when canopy cover was 85%+</p> <p>***For lands where wildlife habitat improvement and wood production are the goals, forests on moist/very moist, rich/very rich soils should be opened to provide more light to understory when canopy closure reaches 80%.</p> <p>***Reducing canopy closure to 60% would result in 40% salmonberry cover. Canopy should be non-uniformly opened.</p>
281	<p>Latta, G., Montgomery, C.A. 2004. Minimizing the cost of stand level management for older forest structure in western Oregon. <i>West. J. Appl. For.</i> 19(4):221-231.</p> <p>1 - Very Relevant to Jackson WHMP</p> <p>This study used an individual tree simulation model ORGANON to search for cost-effective old forest management regimes.(OFS) The opportunity cost of managing for older forest structure was estimated as the value of forgone timber production. Stand management regimes were consistent with those developed by McComb et al 1993, Carey and Curtis 1996, Barbour et al. 1997; typically, 3 thinnings were prescribed between ages 40 and 80. These removed from 40 to 65% of the standing volume on average. Older forest structural attributes were obtained by 100-120 years. Active management may more likely succeed at achieving conservation objectives and at a lower cost than the reserve approach.</p> <p>OFS management involves multiple thinnings. For new stand types, the algorithm almost always prescribed 3 thinnings. These occur, on average, every 20 years beginning at age 40.</p> <p>For existing stand types, as the time horizon was shortened, fewer thinnings were prescribed. See supporting document tables.</p> <p>More volume removed in the thinnings than is typical for commercial timber production. For new stands, the removals are on average, 63, 56 and 40% for the first, second and third thinnings, respectively. Compared to 2-35% for commercial timber productions in western OR. For existing stand types, then the time horizon is long (w=155) the percent volume removal is a little higher than it is for new stand types, about 67% of the standing volume. Shorter time horizons result in less volume removed in each thinning -- 68, 63 and 52% volume removed in first thinning for w=155, 95, and 65, respectively.</p> <p>OFS for older existing stands involves thinning right away: over 80% of existing stand types older than 60 years are thinned within 10 years.</p> <p>Thinning occurred and OFS criteria were met earlier for high-quality sites than for low-quality sites.</p> <p>Time horizon is a limiting factor for most new stand types. Because postponing final harvest is costly, the algorithm favors harvest as early as possible. Nonetheless, over half of the new stand types are held for clearcut harvest until the end of the time horizon at age 155, suggesting that lengthening the time horizon might reduce cost for most stand types. The time horizon is less constraining for existing stand types than for new stand types -- only 10% of the stands are held the full 155 years before final clearcut. Nearly 10% are held for 100 years or less.</p> <p>Opportunity cost of OFS: See tables in supportive link.</p>

	<p>For new stands, the average cost for OFS management is \$148/ac. OFS management is more costly on high-quality sites than on low-quality sites.</p> <p>The cost is higher for existing stands because of the value of the standing timber. Cost increases dramatically as the time horizon is shortened. The relationship b/n cost and site quality is not apparent. OFS management is relatively costly on well-stocked older stands.</p>
237	<p>Lehmkuhl, J. F., S.D. West, C.L. Chambers et al. 1999. An Experiment for Assessing Vertebrate Response to Varying Levels and Patterns of Green-tree Retention. Northwest Sci. 73: 45-63. Part of DEMO study. Pre-treatment sampling completed; discussion of hypotheses and methods. Limited discussion of pre-treatment sampling results (which are presented as rank abundances). 2 - Somewhat Relevant to Jackson WHMP</p> <p>Literature review for arboreal and terrestrial small mammals: Arboreal and semi-arboreal spp found in closed-canopy forest that has developed beyond stem-exclusion stage. This pattern generally attributable to greater compositional and structural diversity found in old forest age classes (Carey 1991, 1995). These spp can be relatively abundant in younger stands with diverse understory composition and dead wood legacies.</p> <p>Most abundant in closed-canopy forests past stem-exclusion stage (sparse herb and shrub layers): red-backed voles, Trowbridge's shrew, shrew-moles</p> <p>Habitat generalists: deer mouse, montane shrew</p> <p>most abundance in dense, ground-level vegetation of early-successional communities and streamside: creeping vole, Pacific jumping mouse</p> <p>High-intensity disturbances will lead to an increase of early-successional small mammal spp and generalists, but note long-term adverse impacts due to elimination of CWD inputs.</p> <p>Of arboreal rodents, Townsend's chipmunk most abundant. Shrews, deer mice and red-backed voles most captured terrestrial mammals.</p> <p>Bats: Detected 5 spp or spp groups: big brown, hoary, silver-haired, Townsend's big-ear, and Myotis spp</p> <p>Amphibians: Notes revisions of amphibian taxa, lack of information on habitat relationships. Much variation in sampling results among study blocks. Amphibian abundance and diversity 2x higher in Washington than in Oregon. 5 spp common to all blocks in WA; 2 on all blocks in OR. Ensatina comprised 54% of all amphibian captures may be suitable for detecting treatment effects across both states. Northwestern salamander and tailed frog in WA common enough to suggest that treatment effects will be detectable.</p>
83	<p>Lehmkuhl, J.F. 2005. Wildlife habitat fragmentation. 2005. Western Forester. November/December:8-9. 3 – Not Relevant to Jackson WHM</p> <p>Forest practices may result in gains for some species, while others may lose habitat, with corresponding short- and long-term effects on population size and persistence. Impacts depend on the species, their habitat requirements, population structure, life history, and the landscape context. Landscape-level issues of habitat distribution and connectivity across ownerships usually need to be addressed through collaboration among private and government land managers, especially for wide-ranging species.</p>
122	<p>Lewis, J. C. and J. M. Azerrad. 2003. Pileated Woodpecker. Pages 29-1 – 29-9 in E. Larsen, J. M. Azerrad, N. Nordstrom, editors. Management Recommendations for Washington's Priority Species, Volume IV: Birds. Washington Department of Fish and Wildlife, Olympia, Washington, USA. 1 - Very Relevant to Jackson WHMP</p> <p>Most nests are in hard snags with intact bark and broken tops, or live trees with dead tops.</p>

	<p>PWP may use up to 11 roosts over a 3-10 month period.</p> <p>Cedar are often preferred as roost trees due to natural hollowing.</p> <p>Mature and OG forest are considered high quality habitat, but forests as young as 40 years are used if large residual snags are present.</p> <p>Shelterwood cuts and clearcuts are occasionally used if substantial foraging habitat is retained.</p> <p>Deciduous riparian habitat is used for foraging activities.</p> <p>Large snags are preferred foraging substrate, possibly because they harbor more insects and larvae than smaller snags.</p> <p>CWD is rarely used for foraging in wet coastal forests.</p> <p>Forest fragmentation may reduce population density and increase vulnerability to predation as the birds are forced to fly between fragmented forest stands.</p> <p>Management activities should focus on providing and maintaining large snags and large decaying live trees for nesting and roosting.</p> <p>Retaining snags and decaying live trees provides suitable nesting and roosting structure for a longer period than retaining/creating only hard snags.</p> <p>Trees, snags and stumps with existing PWP nest cavities and foraging excavations should be retained.</p> <p>Uneven-aged forest management can help to provide large trees and suitable canopy closure to maintain suitable nesting and roosting structure for PWP.</p> <p>Defective and cull trees should be retained during harvest operations.</p> <p>Extending harvest rotations may be one of the most effective means of providing large snags.</p> <p>Average values of given habitat components should be used as management goals.</p> <p>"Adequate snag densities are defined as the combination of nesting, roosting and foraging snag numbers"</p> <p>*** Recommendations: see supporting link</p>
78	<p>Marcot, B.G., Aubry, K.B. 2003. The functional diversity of mammals in coniferous forests of western North America. In: Zabel, C.J., Anthony, R.G., eds. Mammal community dynamics: management and conservation in the coniferous forests of western North America. New York: Cambridge Univ. Press:631-664.</p> <p>3 - Not Relevant to Jackson WHM</p> <p>Proposes that the collective importance of terrestrial mammals to ecosystem structure and function is substantial and that the decline or loss of forest mammal species could have detrimental effects on ecosystem diversity, productivity, or sustainability.</p>
154	<p>Marshall, D.B. 1994. Status of the American Marten in Oregon and Washington. Unpublished Report. Portland, OR. Audubon Society of Portland. 46 p.</p> <p>2 - Somewhat Relevant to Jackson WHMP</p>

	<p>Literature review with section on timber harvest practices. Cites management recommendations of Corn and Raphael (1992) in Wyoming, and studies in California (Sierra Nevada): Martin and Barrett (1991), Hargis and McCullough (1984), Spencer (1981). See separate citations for these studies.</p> <p>Martin habitat requirements include high percentages of late-successional or mature and/or old-growth forests that can accommodate large home ranges. Habitat quality depends on mesic areas, high availability of prey, subnivean access where snow accumulates, a canopy level of at least 40%, and numerous denning sites. Denning sites include cavities in large snags and logs, and subterranean cavities under large logs, stumps and root wads. In the Pacific Northwest, martens use cavities in large diameter live trees and snags. Martens do not cross large open areas except when overhead cover is present, but will enter non-forested areas having cover in summer for berries.</p> <p>Forest fragmentation results in larger home range sizes and lower population sizes under late-successional or old growth conditions fall below the 30 to 50% level. Local extirpations then occur.</p>
316	<p>Marshall, D.D., Curtis, R.O. 2005. Evaluation of silvicultural options for harvesting Douglas-fir young-growth production forests. In Peterson, C.D., Maguire, D.A., eds. Balancing ecosystem values: innovative experiments for sustainable forestry. Gen. Tech. Rep. PNW-GTR-635. Portland, OR: USDA Forest Service, Pac. NW Res. Stn. P. 119-125.</p> <p>2 - Somewhat Relevant to Jackson WHMP part of the Silvicultural Options for Young-Growth Douglas-fir Forests study on the Capitol Forest.</p> <p>Treatments: clearcut, two-age retains 40 tph (similar to shelterwood but overstory trees will be carried through next rotation), patch cut (uneven-aged mosaic of even-aged patches created on 15-yr cycle in 0.6 to 2.0 ha patches, group selection uneven-aged system in which 20% of area harvested at 15-yr intervals in 0.02 - 0.6 ha openings., continued thinning on an extended rotation typical thinning from below), and untreated control.</p> <p>Monitoring residual tree growth, damage and mortality, stand development and yields, costs of harvesting, harvest production, soil disturbance, song bird populations.</p> <p>Initial results, see Curtis (2004) in GTR-598. Costs of harvesting the two-age, patch cut and group selection units were about 1.2 times greater than the clearcut.</p>
230	<p>Mathiasen, R.L. 1996. Dwarf Mistletoes in Forest Canopies. Northwest Sci. 70:61-71.</p> <p>1 - Very Relevant to Jackson WHMP Spotted Owls, marbled Murrelet and several species of squirrels have been found to frequently use mistletoe brooms for nesting.</p> <p>Marten use brooms as resting sites.</p> <p>Sites with mistletoe are suspected of having much greater species diversity than mistletoe free sites.</p> <p>Studies in Colorado have shown that the number and abundance of passerine birds as well as cavity nesting birds is higher in these areas than in non-infested areas. Elk and deer activity was also higher in these stands.</p> <p>A more extensive list of species that are not rare or endangered and also use brooms is provided as well.</p>
283	<p>McComb, W.C. 2001. Management of within-stand forest habitat features. In Johnson, D.H., O'Neill, T.A. Wildlife-habitat relationships in Oregon and Washington. Oregon State Univ. Press. Corvallis, OR.</p>

P. 140-153.

1 - Very Relevant to Jackson WHMP

Silvicultural treatments have partially replaced natural disturbances in managed forests. Natural disturbances include coarse-scale disturbances caused by widespread fire or windstorms and fine-scale (<2 ac.) disturbances due to suppression mortality, root rot, localized windthrow and light ground fire. Although infrequent in old-growth Douglas-fir stands, these canopy gaps are the sites of tree regeneration in mature stands, particularly for shade-intolerant species.

Forest-dwelling wildlife use key structural and compositional features over home range-sized areas or larger: large trees, dead wood, forest floor litter.

Stand management starts with identifying desired future condition. Determine diameter distribution and associated levels of variance for living and dead wood for the wildlife species that are desired. The goal of the silvicultural system is to provide the structure, composition and dead wood distribution in the managed stand to fall within the range of acceptable variability for the wildlife species.

- ID clear objectives for habitat management, i.e. wildlife species
- Identify existing examples of conditions that meet the objectives
- Design prescriptions specific to local conditions that meet the objectives
- Plan the locatin of the stands on the landscape to create landscape patterns that meet the objectives. Determine diameter distribution and associated levels of variance for living and dead wood for the wildlife species that are desired. The goal of the silvicultural system is to provide the structure, composition and dead wood distribution in the managed stand to fall within the range of acceptable variability for the wildlife species.

Even-age management

- Similar to coarse-scale disturbance
- Clearcut – grass-forb stage and shrub stage
- Seed-tree – leaves some vertical structure until residual trees harvested, but duration of grass-forb stand is shorter
- Shelterwood - leaves some vertical structure until residual trees harvested, but duration of grass-forb stand is shorter
- Deferred-rotation system – some vertical structure through the rotation
- Even-age management results in the creation of sharp edges, not beneficial to many wildlife species such as amphibians
- Favors shade-intolerant plant species
- Partial-cut functions similar to clearcut when <10 tpa are retained
- Legacy trees- features that are typical of natural disturbances
- Site preparation – no benefit to most wildlife
- Stand re-establishment – mixed-species variable-density planting favored
- Vegetation management – favors spot control rather than broadcast control, manual control of shrubs
- Thinning – opening the crown favors flycatchers. VDT can produce a wide range of tree diameters.

Uneven-age management

- Group selection or individual-tree selection similar to fine-scale disturbance
- Green trees normally retained
- Stand-level vertical structure high, edge and fragmentation effects are usually low, stand heterogeneity is usually high compared to even-age systems.
- Minimal site prep
- Usually rely on advance regeneration
- Artificial regen feasible within group selection system
- Shade-intolerant species can be regenerated with group selection than with single-tree

	<p>selection.</p> <ul style="list-style-type: none"> • Small patch, group-selection systems or single-tree selection systems that rely on existing advance-regne or large planting stock may eliminate grass-forb stand conditions and reduce the duration of shrub stage. • Many bird spp using group selection stands also found in uncut mature forest • Cutting cycle length, target tree size, thinning intensity all affect the structure and composition of uneven-age stands • Choice of which silvicultural system to use det. By the plant community, site conditions, logging constraints and species. <p>Activities in even-aged stands that enhance conditions for species typical of late seral stages:</p> <ul style="list-style-type: none"> • Legacy retention • Variable-density planting and thinning • Minimize soil disturbance <p>Activities in uneven-aged stands that enhance conditions for late seral stage species:</p> <ul style="list-style-type: none"> • Large target tree size • Longer cutting cycle • Minimize soil disturbance • Small-group or single-tree selection where appropriate • Mange for shade-tolerant species • Maintain high-density groups of regeneration • Legacy retention <p>Non-traditional management systems. See McComb et al. 1993. Stand management for timber and mature-forest wildlife in Douglas-fir forests. J. Forestry 91(12):31-42.</p> <p>Modified single-story stand</p> <ul style="list-style-type: none"> • imitates coarse-scale disturbance but usually small in size • Leave 3-10 live trees/ac and large dead wood • Stand may be recolonized by species associated with mature forests as stand develops, but would not provide adequate habitat for mature forest species until the regeneration develops to a sufficient size. • Useful on steep slopes where havesting costs for uneven-aged management are high. <p>Few-storied stand</p> <ul style="list-style-type: none"> • imitates coarse-scale disturbance but usually smaller in size • Greater variability in tree diameter and vertical structure than single-story stand • Creates stands with 2 or 3 canopy layers and large dead wood • Stand may be recolonized by species associated with mature forests as stand develops, but would not provide adequate habitat for mature forest species until the regeneration develops to a sufficient size. • Useful on steep slopes where havesting costs for uneven-aged management are high. • Useful adjacent to riparian BZ because it would provide a low contiguous canopy cover and a source of large logs for the riparian system. <p>Many-storied stand</p> <ul style="list-style-type: none"> • Imitates fine-scale disturbance. • Uses small group selection cutting to create >3 layers of canopy trees in a mosaic of gaps. • Retain large dead wood • Gaps may have to be larger than most natural canopy gaps to allow natural regeneration of shade intolerant species and to make harvesting more efficient. On gentle terrain, harvesting costs not significantly higher than for clearcutting.
177	McComb, W.C., Spies, T.A., Emmmingham, W.H. 1993. Douglas-fir forests: managing for timber and

	<p>mature-forest habitat. J. Forestry. December 1993:p. 31-42. 2 - Somewhat Relevant to Jackson WHMP Review with computer simulation. Describes mature-forest habitat characteristics: large trees of several species, multilayered canopies. Large snags and logs, deep forest floor litter.</p> <p>Describes natural disturbance in Douglas-fir forests: See Ref. # 283 McComb 2001. Ecological importance of disturbance: Size and shape, intensity, frequency</p> <p>Residual organic material after disturbance can influence the direction of succession and the rate of subsequent development. Remnant structures provide habitat for mature-forest species. Disturbances that cause gaps in mature and old-growth forests also produce snags and logs, and subsequent vegetative growth enhances the stand's vertical complexity.</p> <p>Computer simulation: Silvicultural goal for stands managed to provide habitat for mature-forest wildlife and timber: provide the features found in a natural stand during the development of its managed counterpart. See supportive link figures. 4 approaches in this article: single-story, few-storied, many-storied, and mature-forest restoration. The first two imitate coarse-scaled disturbances; the third is patterned after fine-scale natural disturbance; the fourth develops a young plantation into a stand with mature-forest structures.</p> <p>Single-storey application: similar to clearcutting or shelterwood, but reserve 2 remnant tpa larger than 30 in dbh, and 6 snags larger than 25 in dbh. Regen was 265 tpa, 85% Douglas-fir and 15% grand fir and hardwoods. Age age 45 yrs, 30% of the 8 to 20 inch trees thinned. At age 70 volume predicted to be 49 mbf/acre. Variable density thinning could be used to produce a stand of heterogeneous tree sizes within an even-aged stand. This hypothetical stand might begin to provide habitat for mature-forest spp after about 70 yr</p> <p>Few-storied application: Stands with 2 or 3 canopy layers can be created either by regenerating 2 or 3 age classes or by regenerating a single age class composed of 2 or 3 spp with different growth rates and potential sizes. Shelterwood with reserves (1st approach) applicable where existing old stands are being cut and where windthrow is not likely. Mixed-species clearcut (2nd approach) in existing young plantations or where windthrow and root-rot potential is high. In this simulation, 6 tpa >30 in dbh and 4 snags/acre larger than 24 in dbh. Regen (265 tpa) as in single-storey app. Create 3 snags/ac at age 35, thinned at age 45 yrs to 50 tpa, underplanted with 265 tpa (23% Douglas fir, 77% grand fir. One additional snag/ac created from the 55 y.o. trees. Reduce regen stocking by 70% at age 70. Lengthy discussion of volumes and comparisons with clearcuts, and other options to produce greater diversity and vertical structure. Predicts cavity-nesters of mature forests might use these stands within 50 yrs.</p> <p>Many-storied application: Group and single-tree selection systems designed to produce large tree diameters could be used here. A 115-y.o. stand was projected for 70 yrs based on a 25-yr cutting cycle. Regen was 120 tpa (13% Douglas-fir, 87% grand fir) following each entry. PCT regen to 50-60% fo full stocking, with selection for douglas-fir and against grand fir. Replacements for snags,logs and large green trees could be recruited during each cutting cycle. Lengthy discussion of additional details.</p> <p>Plantation restoration: A 40 y.o. plantation (319 tpa) thinned to 81 tpa. Planted to 265 tpa (28% Douglas fir and 72% grand fir). Trees allocated for snag creation at age 45, age 70 and age 110. Twenty yrs after thinning and regen, predicted similarity b/n the plantation and an unmanaged 80 y.o. stand was</p>
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	<p>67%. Additional thinnings and resulting volumes discussed.</p> <p>Used ORGANON to develop stand predictions: basal area, volume and mortality. Used Marcot 1991 Snag Recruitment Simulator model to predict snag abundance. All snags created from green trees or suppression mortality. Assumed advance regen would be maintained to enhance species composition, competing vegetation control might be needed, no major blowdown, retained green trees' have form to increase post-release growth rates. Starting points: A 115 y.o. unmanaged stand for the single, few and many-storey examples, and a 40 y.o. plantation for the mature forest restoration example.</p>
174	<p>McDonald, P.M. and P.E. Reynolds. 1999. Plant Community Development After 28 Years in Small Group-Selection Openings. Research Paper PSW-RP-241. Albany, CA: PSW Res. Stn. USDA Forest Service; 17p.</p> <p>In 1963, small openings (9, 18 & 27 m diameter, measured from drip-line to drip-line) were created by timber harvest, with ground scarification to reveal bare mineral soil and virtually no competing vegetation.</p> <p>In larger openings and on south aspects, plants developed better and more plants were able to establish.</p> <p>Between the 11th and the 28 year post-initiation:</p> <ul style="list-style-type: none"> >> number of species of conifer and hardwood seedlings remained constant, >>shrub species doubled, >>forbs increased by 50%, >>grass species increased then leveled off at 11th year levels. <p>28 years post clearing, shrubs in the small openings were those that tolerate shade.</p> <p>The 2 larger opening sizes had significantly higher shrub density than the small openings.</p> <p>Forb and grass densities were not statistically different among opening sizes.</p> <p>Fern density was significantly different between the 9 and 27 meter openings.</p> <p>Southern aspect created greater density of shrubs, forbs, grasses and ferns.</p> <p>Shade tolerant conifers were able to establish 25 years post gap creation.</p> <p>The 9m diameter openings were too small for development of most vegetation. Roots of adjacent trees likely extend throughout the gap and remove resources. However, shade tolerant species found this gap size quite suitable.</p> <p>Using group selection cuttings, stands can be regenerated with a diversity of species while maintaining high forest cover, and help to form a spatially distinct age class.</p>
315	<p>Montigny, Louise de. 2005. Silviculture treatments for ecosystem management in the Sayward - the STEMS experiment. In Peterson, C.D., Maguire, D.A., eds. Balancing ecosystem values: innovative experiments for sustainable forestry. Gen. Tech. Rep. PNW-GTR-635. Portland, OR: USDA Forest Service, Pac. NW Res. Stn. P. 89-95.</p> <p>2 - Somewhat Relevant to Jackson WHMP</p> <p>STEMS replicates the Silviculture Options for Harvesting Young-Growth Production Forests project of WDNR and USDA FS-PNW Res. Stn. STEMS is conducted on Vancouver Island</p> <p>Treatments include (extended rotation (unharvested control), extended rotation with CT, CC with reserves (0.3 ha), modified patch cut (0.5 - 3 ha), group selection (13% area cut every 10 yrs,</p>

	<p>0.06 to 0.5 ha. opening) , uniform dispersed retention (40 tph) and aggregate retention. Harvests initiated in 2001.</p> <p>Monitoring tree growth and stand development, CWD, windthrow, harvest cost and productivity, soil disturbance, harvest damage to residuals.</p> <p>Initial results presented on windthrow, harvest costs, tree damage, merch volume.</p>
17	<p>Muir, P.S., Mattingly, R.L., Tappeiner, J.C., Bailey, J.D., Elliott, W.E., Hagar, J.C., Miller, J.C., Peterson, E.B., Starkey, E.E. 2002. Managing for biodiversity in young Douglas-fir forests of western Oregon. US Geol. Surv., Biol. Res. Div., Biol. Sci. Report USGS/BRD/BSR -2002-0006. 76 pp.</p> <p>1 - Very Relevant to Jackson WHMP</p> <p>Management recommendations:</p> <ul style="list-style-type: none"> **Thin young (<60 y.o) dense forests; in some cases, begin thinning at 10-20 yrs and continue until 40-50 yrs. **Variable-density thinning **Protect large (>50 cm diameter) CWD **Protect remnant old trees that are substrate for epiphytes **Retain hardwood trees and shrub spp that provide substrate for epiphytes, food for arthropods, and cavities **Be alert for exotic spp **Adapt thinning prescriptions to individual site and stand conditions and management objectives **Multiple thinning entries to prevent canopy closure on highly productive sites. **For bird populations, use thinning, but leave some unthinned areas. Because breeding bird territories often encompass 5-10 ha, manage at this scale or larger. <p>Retain and promote understory and midstory vegetation; relatively heavy thinnings and irregular spacing of residual trees</p> <p>Proposed thinning guidelines:</p> <ul style="list-style-type: none"> *Retain all existing old, remnant trees, snags and CWD *Retain large trees with large limbs ("wolf trees") *Retain hardwoods across a range of size classes, including large trees in midcanopy and higher *Protect /encourage tall hardwood shrubs, especially those with old stems *Leave sufficient understory conifer regen for development of multistoried stands *Provide for presence of herbs and grasses in forest stands *Use VDT, including heavy thinning (to 50 tph) in portions of young stands. *Promote within-stand and landscape-level diversity; leave some areas unthinned.
226	<p>Nelson, C.R., Halpern, C.B. 2005. Edge-related responses of understory plants to aggregated retention harvest in the Pacific northwest. Ecol. Appl. 15(1):196-209.</p> <p>2 - Somewhat Relevant to Jackson WHMP</p> <p>Part of DEMO study. Field study of short-term (1- and 2-yr) responses of understory plants to disturbance and creation of edges. See #214 for experimental design.</p> <p>2 yrs post-treatment, aggregates had gained an avg. of 2 forest spp (vs a loss of two in adjacent harvested areas) and less than 1 early-seral species (vs a gain of 9 in adjacent harvest areas). Aggregates supported populations of late-seral spp that disappeared from or declined in harvested areas.</p> <p>Aggregates showed edge-related changes in plant abundance: 1/3 of common understory herbs declined in cover toward the edge, changes in community comp were distinctly higher within 5 m of the edge vs. the center of the aggregate. Early-seral spp didn't establish in aggregates; only within 10 m of the edge. Herbaceous spp showed larger declines in abundance with proximity to edge than did shrubs; declines more prominent over time.</p>

	Over short time frames, aggregates of at least 1 ha in size may host late-seral plant spp.
203	<p>North, M., Chen, J., Smith, G., Krakowiak, L., Franklin, J. 1996. Initial response of understory plant diversity and overstory tree diameter growth to a green tree retention harvest. Northwest Sci. 70(1):24-35.</p> <p>2 - Somewhat Relevant to Jackson WHMP Field study examined response of understory plant diversity and basal area growth of retention trees 16 months and six years, respectively, after a green tree retention harvest (retaining 27 tph) in Seattle City Watershed. Both units replanted with tree seedlings at 740 tph.</p> <p>3 adjacent treatment areas: a clearcut, a dispersed green tree retention, and intact 65 yo forest.</p> <p>After 60 months, herb and shrub spp richness and evenness were significantly higher in the GTR cut than in the other 2 understory treatments. Although overall spp composition of the GTR was closer to the clearcut than the forest, the GTR retained more spp and cover of shade-tolerant plants important for maintaining understory diversity as canopy closure reduces understory light.</p> <p>Avg. response for GTR stands in HJ Andrews Experimental Forest, (Eugene, OR) thinned to 20, 43, and 45 tph 6 yrs harvest was a 15% reduction in increment growth compared to the control stands.</p>
14	<p>Public Utility District No. 1 of Snohomish County and City of Everett, Washington. 1988. Wildlife Habitat Management Plan, Henry M. Jackson Hydroelectric Project, 3 Vol., Paging various.</p> <p>1 - Very Relevant to Jackson WHMP</p>
313	<p>Puettman, K.J. 2004. Do innovative experiments lead to innovative silvicultural systems? In Peterson, C.D., Maguire, D.A., eds. Balancing ecosystem values: innovative experiments for sustainable forestry. Gen. Tech. Rep. PNW-GTR-635. Portland, OR: USDA Forest Service, Pac. NW Res. Stn. P. 49-53.</p> <p>2 - Somewhat Relevant to Jackson WHMP Lists long-term experiments in WA, OR and BC that investigate silvicultural alternatives to traditional systems. Most experiments initiated in mid-1990's and later. Most experiments provide information on a range of ecosystem responses, including overstory trees, understory, vegetation, mycorrhizal associations, and animal habitat and populations.</p>
263	<p>Reutebuch, S.E., Haring, C.A., DeBell, D.S., Marshall, D.D., Curtis, R.O. 2002. Silvicultural Options for Multipurpose management of west-side Pacific Northwest forests. In: Parker, S., Hummel, S.S., compilers. Beyond 2001: A silvicultural odyssey to sustaining terrestrial and aquatic ecosystems. Pro. 2001 Natl. Silvicultural Workshop, May 6-10, Hood River, OR. Gen. Tech. Rep. PNW-GTR-546. Pac. NW Res. Stn., Portland, OR. USDA Forest Service, pp. 38-46.</p> <p>1 - Very Relevant to Jackson WHMP Describes long-term research study setup by Westside Silvicultural Options Team of the PNW research station (USFS). Authors point out that there are many new silvicultural approaches, but little research or operational experience that validate successful outcomes of new approaches to produce wildlife habitat, diversity, heterogeneity of stand structures, old growth features, etc. while still producing wood products. No young stands have been managed for an extended period under the proposed alternative methods. Most of the existing work with alternatives to even-age management in the douglas-fir region was done in old growth stands and has little relevance to management of young-growth stands.</p> <p>3 large-scale studies will focus on major stages of managed stands: **early development (precommercial thinning) **midrotation (commercial thinning) **regeneration harvest</p>

	<p>Objectives related to managing for wood production, wildlife habitat and other forest resource values.</p> <p>All 3 studies will measure response of overstory trees and understory plant species, and also CWD</p> <hr/> <p>Young Stands: Experiments set up in Mt. St. Helens Nat'l Volcanic Monument, young, vigorous uniform Douglas-fir plantations, planted in mid-1980s. Treated in 1994-95. Remeasured 3 and 5 yrs later.</p> <p>Study goals: 1. Test how silviculturally induced variation in tree spp composition and stand structure affect plant and animal populations. 2. Quantify the effects of different silvicultural regimes on tree and stand characteristics and production of forest products.</p> <p>5 treatments for young stands: 1. Control plots. Primarily Douglas-fir 680 tpa, one canopy layer, little understory veg. 2. Thinning to 50% of density with uniform tree spacing, and no alteration of spp composition. Possible future commercial thinning, retaining largest, most vigorous Douglas-fir in uniform spacing. 3. Uniform thinning as in 2., with evening spaced openings (40 x 40 ft). Supplemental plantings of red alder, western hemlock and western redcedar. Future commercial thinning to emphasize increasing tree species diversity rather than uniformity. 4. Variable density thinning with variable-size openings to increase structural heterogeneity. Stands evenly thinned as in 2., then openings of 30 x 30 ft, 40 x 40 ft., and 50 x 50 ft. created. No underplanting. Future commercial thinning emphasizing increasing heterogeneity and tree species diversity--only allow harvest of Douglas-fir and expand or create new openings. 5. Treatment as in 4., but interplant openings with red alder, western hemlock and western redcedar. 30 large tps fertilized--for future snag production. Future commercial thinning to accelerate development of multi-layered, uneven-aged mixed-species stands.</p> <hr/> <p>Midrotation stands: Westside Silvicultural Options and the Ecological Foundations of Biodiversity Teams from the Olympic Forestry Sciences Lab designed the Olympic Habitat Development Study of silvicultural options for closed-canopy midrotation stands on the Olympic Peninsula. Study stands are 30- to 70-yr stands of Douglas-fir, western hemlock and Sitka spruce. Pretreatment baseline data on small mammal and amphibian populations, understory species, and CWD quantity collected from 1995 - 1998. Treatment of some blocks in 1997 - 99. Remaining blocks delayed. Some post-treatment surveys completed.</p> <p>Study Goals: 1. Test efficacy of specific mgt. practices to accelerate late-successional stand structure and plant and animal communities. 2. Test if accelerating the development of late-successional structures in closed-canopy midrotation stands will increase habitat value for terrestrial amphibians and small mammals. 3. Develop and test operational prescriptions that allow wood production consistent with sustainable ecosystems.</p> <p>Variable-density thinning: 10 % of the area in no-cut patches to protect existing snags and forest floor patches, 15% in small (65 ft x 65 ft) gaps, 75% lightly thinned from below (removal of 30% of basal area). CWD treatments.</p> <p>5 treatments for midrotation stands:</p>
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	<ol style="list-style-type: none"> 1. Untreated control 2. VDT with scattered slash and logs. Additional trees felled to supplement CWD levels. 3. VDT with scattered slash and clumped logs. Additional trees felled to supplement CWD levels. 4. VDT with slash piles and clumped logs, and supplemental planting of trees in gaps. Additional trees felled for CWD. 5. VDT with scattered slash and no supplement CWD. <hr/> <p>Regeneration harvest methods: Silvicultural options for harvesting young-growth forests, in collaboration with DNR on Capitol Forest. First block harvest in 1998, replanted in 1999. Post-treatment song bird survey.</p> <p>Study goals:</p> <ol style="list-style-type: none"> 1. Evaluate biological, economic and visual effects of alternative timber harvest and management regimes for young-growth forests. 2. Provide demonstrations of contrasting silvicultural systems that are biologically feasible for managing young-growth forests. <p>Treatments for young-growth stands;</p> <ol style="list-style-type: none"> 1. Clearcut and manage similar to traditional even-aged standards, with PCT and CT as rel. stand densities exceed desired targets. 2. Retained overstory - Resembles shelterwood, but residual trees carried through next rotation. 15 evenly spaced tpa retained. 3. Small patch cutting - An even-aged system with small openings (1.5 to 5 ac.) created over 20% of the unit. May concurrently thin remainder of stand. Future thinning if densities exceed targets. 4. Group selection - An uneven-aged system with evenly-spaced openings (up to 1.5 ac.) created over 20% of the unit. May concurrently thin remainder of stand. Future thinning if densities exceed targets 5. Extended rotation with commercial thinning. Thin from below, removing 30% of basal area throughout stand. Future thinning if densities exceed targets. 6. Unthinned control <p>Regeneration in treatments 1-4 will be by planting in openings >0.1 ac. No planting in 5-6.</p>
247	<p>Risenhoover, K.L., Murden, S.B. 2006. Managing for wildlife in intensively managed forests: a landowner perspective. In Harrington, T.B., G.E. Nicholas, tech. eds. Managing for wildlife habitat in west-side production forests. Gen. Tech. Rep. PNW-GTR-695. Portland, OR:USDA Forest Service, Pac. NW Res. Stn. Pp. 107-116.</p> <p>2 - Somewhat Relevant to Jackson WHMP</p> <p>Observations and studies from Port Blakely foresters: Emphasized retention of legacy features: stumps, green trees, wildlife(defective) trees, logs and snags in even-age managed forests because within-stand structural diversity is low.</p> <p>Woody debris has a mulching effect. Benefits include moisture retention and heat abatement for wildlife--results of a study forthcoming. Reforestation isn't greatly impeded by logging slash; anecdotal evidence that there is less browse on tree seedlings.</p> <p>Understory conifers are retained to increase diversity</p> <p>RMZs over time will account for a large % of the landscape. Will develop into mature age classes, provide connectivity for wildlife, and source of large snags</p> <p>Ecologically sensitive sites: cliffs, caves, rock outcrops, seeps and spring.</p> <p>Don't replant natural meadows.</p> <p>Misgivings about created snags: decay processes not the same as in natural snags. More Weyerhaeuser studies coming out soon. Old Weyco studies compared snag longevity from</p>

	different methods. Drought-, lightning- and wind-killed snags lasted the longest. Snags killed by herbicide and laminated root-rot didn't last as long.
265	<p>Rose, C.F., Muir, P.S. 1996. Green-tree retention: consequences for timber production in forests of the western Cascades, Oregon. <i>Ecol. Appl.</i> 7(1):209-217.</p> <p>2 - Somewhat Relevant to Jackson WHMP</p> <p>Western hemlock stands studied retrospectively: 70-110 y.o. (regen) and 70-110 y.o. with an overstory of large trees 200+ y.o. (remnants). 15 remnant tph can be retained following harvest w/o significant reductions in regen growth and total stand BA remains fairly constant across remnant densities. At <45 remnant tph decline in regen BA related to combined effect of shading (or other suppressive effects) and space occupancy by remnants. Part of the effect of remnants on regen results from remnants' occupation of space, making it unavailable to the regen. BA of western hemlock regen increased as that of Douglas-fir decreased. Results differ from simulation models (Hansen et al 1995), which predict reductions in regen growth and total stand BA at lower levels of retention.</p> <p>Silvicultural techniques could moderate the decline in both Douglas-fir regen BA and regen BA across all species with increasing remnant density. Douglas-fir could be planted in more open areas of a site harvested with green tree retention, while regen of western hemlock or other shade-tolerant species could be facilitated in areas with more canopy cover.</p> <p>Remnant density was not related to tree-species diversity in the regen.</p>
303	<p>Sallabanks, R., Arnett, E.B., Marzluff, J.M. 2000. An evaluation of research on the effects of timber harvest on bird populations. <i>Wildl. Soc. Bull</i> 28(4):1144-1155.</p> <p>3 - Not Relevant to Jackson WHMP</p> <p>A review of 95 studies published from 1972 to 1997 that examined relationships between timber harvest and songbird populations.</p> <p>Most research was short-term (1-2 yrs), not replicated, correlational and did not address cause-and-effect relationships. Most research included some habitat data but did not use multivariate analysis to examine bird-habitat relationships. Few studies measured avian demographic parameters such as nest success or survivorship; most studies measured avian density or abundance. Incorporating experimental treatments to provide pre- and post-timber harvest comparisons was rare.</p> <p>Future research should 1) be more long-term, 2) incorporate better experimental design, 3) measure parameters related to avian fitness and population viability. "Without detailed analyses of bird-habitat relationships using multivariate approaches, the specific structural attributes of forests that attract or deter birds may remain obscure. Knowing that a species is more abundant in a clearcut than nearby midsuccessional forest is useful information, but unless the key habitat elements (e.g., snag density, understory cover) responsible for the difference also are identified, precise management recommendations cannot follow."</p> <p>Cites Hayes et al 1998 for experimental design, including replication, randomized treatment plot, and length of data-gathering period.</p>
218	<p>Schwarz, P., Maguire, D.A., Mainwaring, D. 2005. Projections of future overstory stand structure and composition following variable-retention harvests in the Northwestern United States. In: Peterson, C.E., Macuire, D.A., editors. <i>Balancing ecosystem values: innovative experiments for sustainable forestry. Proceedings of a conference. Gen. Tech. Rep. PNW-GTR-635. USDA Forest Service. Pp. 211-214.</i></p> <p>2 - Somewhat Relevant to Jackson WHMP</p> <p>Part of DEMO project. Experimental design described in #214. Computer simulation with ORGANON growth and yield model; understory trees simulated using SYSTUM-1. Replanted from 500 to 750 tph. Expect relatively closed canopy in 15 to 25 yrs. Goal of the simulation</p>

	<p>was to project future structure of DEMO treatment units and facilitate future management planning by the team.</p> <p>Illustrated alternative management scenarios at 2 sites (Capitol Forest and high-elevation site in Cascades) under 4 scenarios;</p> <ul style="list-style-type: none"> *no management *understory management in which stands were grown for 50 yrs, then 50% of trees removed *understory and overstory management, in which stands thinned proportionally when they reach relative density of 55 down to relative density of 35 *thinning-from-below in which thinned trees thinned at RD 55 down to RD 35 <p>Visuals provided for 15% dispersed retention at yrs 1, 15, and 100 for Capitol Forest with no management scenario. At 100 yrs the stand is 2-storied but canopy appears closed. Output from all treatments showed closed canopy long before 100 yrs, even where retaining only 15% of the original basal area.</p> <p>Visuals provided for all scenarios at higher-elevation site (Paradise Hills). Understory scenarios accrues more basal areas than either the understory/overstory or thin-from-below scenarios but less than the baseline. Density of young trees in the thin-from-below scenario noticeably lower than density in the understory/overstory scenario.</p> <p>At 40% retention level, although overstory production for the 100-yr period is comparable between the aggregated and dispersed retention, the well-distributed shade of dispersed trees limits growth/development of the understory compared to uncut aggregates of the same basal area. At 15% retention, understory production is roughly equivalent for both aggregated and dispersed retention. However, with the significant spacing given to overstory trees in the dispersed pattern, overstory production is more than twice the amount observed in the aggregated pattern. See linked table for results of DEMO treatment, simulation scenario on overstory vs. understory production.</p>
169	<p>Spencer, W.D. 1981. Pine marten habitat preferences at Sagehen Creek, California. M.S. Thesis. Univ. of Calif., Berkeley, CA. 121pp.</p> <p>2 - Somewhat Relevant to Jackson WHMP</p> <p>For forest stands adjoining riparian areas and meadows, "timber harvest should be by single-tree selection (maintaining 40-50% canopy closure) or small group selection (<0.25 ha). At least 8 snags/ha >38 cm dbh, including 1 >70 cm dbh, should be retained, along with 6 logs/ha > 60 cm dbh. At least 12 fir trees/ha 70 cm dbh should be retained to provide for future snag recruitment."</p> <p>In more distant forest stands, "a greater variety of silvicultural practices are acceptable...where maintenance of habitat density and travel corridors are the major objectives. Clearcuts should be <100 m across with scattered trees left within them, and travel corridors of at least 30% canopy closure should be left connecting important habitats."</p> <p>Cited in Marshall, 1994</p>
82	<p>Spies, T.A. 2005. Scaling up from stands to landscapes. In: Peterson, C.E., Maguire, D.A., eds. Balancing ecosystem values: innovative experiments for sustainable forestry. PNW-GTA-635. Portland, OR:US Forest Service, Pac. NW Res. Stn.; 187-190.</p> <p>3 - Not Relevant to Jackson WHM</p> <p>Stand-level experiments are critical to understanding the effects of innovative silvicultural practices on biological diversity. The author examines some lessons learned from landscape-scale modeling studies that incorporate stand-level information. Coastal Landscape Analysis and Modeling Study.</p>
288	<p>Steeger, C. and M. Machmer. 1995. Use of Trees by Cavity Nesters in Managed and Unmanaged</p>

	<p>Interior Cedar-Hemlock Stands of Southern B.C. In: Bradford, P., T. Manning and B. l'Anson eds. Wildlife Tree/ Stand-Level Biodiversity Workshop Proceedings. Victoria, B.C. October 1995. 45-54. 2 - Somewhat Relevant to Jackson WHMP Study conducted in SE B.C.</p> <p>Mean dbh for active nest snags was 41.8cm Mean height for active nest snags was 20.6m</p> <p>Mean dbh for feeding trees was 30.3 cm Mean height for feeding trees was 13.4m</p> <p>Mean dbh of Douglas-fir used for bat roosts was 46.0 cm; mean height was 24.0 m, and a vast majority (55.6%) of these roost were in woodpecker cavities.</p> <p>Authors caution that if logging occurs during the main breeding season (May - July) that nestling bird and mammals occupying the nest trees will be unintentionally destroyed.</p>
61	<p>Stevenson, J.D., K.L. MacKenzie, and T.E. Mahon. 1998. Response of Small Mammals and Birds to Partial Cutting and Clearcutting in NW BC. Forestry Chronicle 74:703-713. 2 - Somewhat Relevant to Jackson WHMP Alternative Silviculture Systems research initiative of the BC Ministry of Forests (under BC/Canada Forest Resources Devel. Agreement).</p> <p>Field study of small mammal and bird abundance after 2 intensities of partial cutting (LRT - 30% volume removal similar to single- tree and group selection system, and HRT - 60% volume removal similar to an irregular shelterwood system), compared to CC - clearcuts and UC - uncut stands.</p> <p>The 4 treatments differed primarily in tree basal area and proportion of area in canopy openings. Existing snag inventory dropped as result of harvest. Basal area of dead trees less after treatment than in UC. Mean diameter of both live and dead trees, and volume of downed logs, did not differ significantly by treatment, while the mean diameter of downed logs in CCs was significantly less than in UC.</p> <p>Small mammals: southern red-backed vole (<i>Clethrionomys gapperi</i>)(most abundant in all treatments), meadow vole (<i>Microtus pennsylvanicus</i>), deer mouse, common shrew, dusky shrew (<i>Sorex monticolus</i>).</p> <p>Red-backed vole more abundant in 1st year after LRT than UC. Other spp did not show significant differences by treatment, although the few meadow voles captured were all in CC.</p> <p>2nd year increase in deer mice and meadow voles. Red-backed voles most abundant in LRT, followed by UC and HRT, least abundant in CC. Deer mice more abundant in CC than UC. Meadow voles more abundant in CC than all other treatments. Shrews present in similar numbers in all treatments.</p> <p>Creation of openings in closed-canopy conifer forest increases small mammal abundance and diversity. With heavy canopy removal (CC or shelterwood), the most dramatic response is an increase in meadow voles and a decrease in red-backed voles.</p> <p>Birds: 34 spp used in analysis. Data combined for both post-treatment yrs. Bird communities in LRT and HRT more similar to UC than to CC, but limited sample size made it difficult to test for differences in detections of species as a function of treatment. Several spp (chestnut-backed chickadee and winter wren) had low abundance in CC, but no clear preference among the partial cuts and UC. Sapsucker and hairy woodpeckers frequently detected in CCs that had unharvested aspen trees with nest cavities, but foraged in nearby UC. Tree swallows also</p>

	<p>nested in tree cavities but only foraged in CC. Lincoln's sparrow and chipping sparrow only detected in CC. Robin and junco common in all treatments but most common in CC. Preference of Hammond's flycatcher for partial cuts was expected. Unexpected was the preference for partial-cut treatments by bark-cleaning spp (three-toed woodpecker, hairy woodpecker, brown creeper, red-breasted nuthatch). More results of this sort presented in this paper.</p> <p>General conclusions: HRT retained substantial abundance of most bird spp associated the UC, but was also used by some open-habitat spp more typical of CC.</p> <p>By varying the intensity and spatial pattern (dispersed or clumped) of timber harvest within a stand, can create the range of conditions favored by different guilds (see Hansen et al 1995 for definitions).</p> <p>The value of CC to some bird spp can be enhanced by leaving scattered individual mature trees or patches of trees.</p> <p>Limitations to this study and partial cutting: **With repeated harvest entries, expect a decline in abundance of snags and CWD **This study had abundant UC forest adjacent to treatment stands; may have influenced the use of treatment stands by some spp.</p>
308	<p>Sullivan, T.P., Sullivan, D.S. 2001. Influence of variable retention harvests on forest ecosystems. II. Diversity and population dynamics of small mammals. J. Appl. Ecol. 38:1234-1252. 3 - Not Relevant to Jackson WHMP Field study in southern BC in clearcut, single seed-tree, group seed-tree, patch-cut and uncut forest sites in Douglas-fir lodgepole-pine zone. Patch-cut system harvests timber from < 1 ha units dispersed over the stand. Experimental design described in Sullivan, Sullivan & Lindgren (2001).</p> <p>Hypothesis 1: The abundance and diversity of small mammals will decline with lower levels of tree retention. Contrary to hypothesis, mean total abundance of small mammals was similar among sites, and mean spp richness and diversity of small mammals was lowest in the uncut forest but similar across the 4 harvest treatments.</p> <p>Mean overall abundance of <i>Microtus</i> spp higher on clear-cut sites than single seed-tree, group seed-tree, patch-cut or uncut forest sites. Overall mean abundance of southern red-backed vole was similar in uncut forest and group seed-tree sites, which were both higher than patch-cut, clear-cut or single seed-tree sites.</p> <p>Recruitment of new <i>Microtus</i> spp differed significantly among sites, declining from clear-cut to uncut forest. Recruitment of red-backed vole exhibited the opposite trend. Survival of each vole species was similar across treatment sites.</p> <p>Hypothesis 2: The abundance, reproduction, and survival of <i>Microtus</i> spp. And southern red-backed vole populations will decline and increase, respectively, with the basal area and density of residual trees after harvest. This hypothesis was supported: Mean abundance of <i>Microtus</i> spp was inversely, and that of red-backed vole positively, related to mean basal area and density of residual trees after harvest. Mean abundance of <i>Microtus</i> spp also inversely related to percent cover and crown volume index of residual trees, and positively related to number of lodgepole pine cones in logging debris.</p> <p>Hypothesis 3: Habitat heterogeneity generated by variable retention harvest will limit <i>Microtus</i>, thereby reducing feeding damage to tree seedlings. Vole feeding damage to planted pine seedlings highest in the patch-cut sites, caused mainly by red-backed vole rather than</p>

	<p>microtines.</p> <p>The group seed-tree and patch-cut systems achieved both aims of maintaining red-backed vole and preventing microtine outbreaks.</p>
28	<p>US Forest Service. 2002. Canopy gaps and dead tree dynamics: poking holes in the forest. Science Findings. PNW 43.</p> <p>1 - Very Relevant to Jackson WHMP</p> <p>Within gaps, temperatures (air & soil) are higher, increased moisture leads to increased decomposition and therefore greater nutrient availability, thus increasing the productivity of the surrounding forest.</p> <p>Plant species diversity is higher in gaps than the surrounding forest.</p> <p>Douglas-fir growth was low except in the largest gaps, hemlock growth increased dramatically with gap size, and silver fir responded least to gap size.</p> <p>Overstory tree growth increased around the gaps, suggesting that a below-ground "gap" is also created.</p> <p>Southern areas within gaps had abundant growth of a wide range of species.</p> <p>Douglas fir was more successful in gaps of 0.33 ac or larger, faring especially well in the northern portions with more sunlight. Hemlock and silver fir were more opportunistic, and had higher growth rates in smaller gaps and shady areas of larger gaps.</p> <p>Gaps with diameters of about 80' (0.10 ac) had the highest available moisture. Larger gaps saw an increase in moisture and higher temperature, leading to expedited decomposition and greater nutrient availability.</p> <p>"Many national forest managers are incorporating gaps as part of thinning prescriptions designed to diversify dense plantings and accelerate development of late-successional conditions"</p>
285	<p>USDA Forest Service. 1994. Standards and Guidelines for Management of Habitat for Late-Successional and Old-Growth Forest Related Species Within the Range of the Northern Spotted Owl, Attachment A to the Record of Decision for Amendments to Forest Service and Bureau of Land Management Planning Documents Within the Range of the Northern Spotted Owl.</p> <p>1 - Very Relevant to Jackson WHMP</p> <p>Adequate numbers of large snags and green trees are especially critical for bats because these trees are used for maternity roosts, temporary night roosts, day roosts, and hibernacula. Large snags and green trees should be well distributed throughout the matrix because bats compete with primary excavators and other species that use cavities. Day and night roosts are often located at different sites, and migrating bats may roost under bark in small groups. Thermal stability within a roost site is important for bats, and large snags and green trees provide that stability. Individual bat colonies may use several roosts during a season as temperature and weather conditions change. Large, down logs with loose bark may also be used by some bats for roosting.</p> <p>Removal of snags following disturbance can reduce the carrying capacity for these species for many years.</p> <p>Regarding green tree areas, for many species, benefits will be greatest if trees are retained in patches rather than singly. Because very small patches do not provide suitable microclimates for many of these organisms, patches should generally be larger than 2.5 acres.</p>

	<p>To the extent possible, patches and dispersed retention should include the largest, oldest live trees, decadent or leaning trees, and hard snags occurring in the unit. Patches should be retained indefinitely.</p> <p>As a minimum, snags are to be retained within the harvest unit at levels sufficient to support species of cavity-nesting birds at 40 percent of potential population levels based on published guidelines and models. The objective is to meet the 40 percent minimum standard throughout the matrix, with per-acre requirements met on average areas no larger than 40 acres. To the extent possible, snag management within harvest units should occur within the areas of green-tree retention. The needs of bats should also be considered in these standards and guidelines as those needs become better known.</p> <p>Specifically, the Scientific Analysis Team recommends that no snags over 20 inches dbh be marked for cutting. The Scientific Analysis Team recognizes, however, that safety considerations may prevent always retaining all snags.</p> <p>Site-specific analysis, and application of a snag recruitment model (specifically, the Forest Service's Snag Recruitment Simulator) taking into account tree species, diameters, falling rates, and decay rates, will be required to determine appropriate tree and snag species mixes and densities. If snag requirements cannot be met, then harvest must not take place.</p> <p>Snag requirements are developed by the National Forests and BLM Districts for specific forest cover types, and these may be further broken down by geographic location. The intent is to tailor the requirements to those species that are actually expected to occur in an area.</p> <p>The most current available research will be used to determine to what degree the requirements for these other species are met by these snags or whether additional snags are needed to meet these other species objectives.</p>
71	<p>Van Pelt, R. 1995. Understory Tree Response to Canopy Gaps in Old-Growth Douglas-fir Forests of the Pacific Northwest. Seattle, WA. Univ. of WA. PhD Dissertation; 237p. 1 - Very Relevant to Jackson WHMP Master's thesis available from UW library.</p> <p>Variability in the canopy was highly correlated with understory light levels and shrub cover values.</p> <p>Spatial patterns of regeneration trees were poorly correlated with canopy height, canopy density and location of gaps</p> <p>Light environment is highest 18-20m north of the gap center.</p> <p>Understory trees that responded to gap formation did so within 5 years, but many did not show a response.</p> <p>Shrub and herb cover showed stronger correlation with canopy gaps and were more adaptable to changes in the canopy environment.</p> <p>Noted that Spies et al 1990 reported that median gap size in OG DF forests was 85m² (765ft²), small enough that only shade tolerant species can take advantage.</p> <p>Hemlock crowns are more densely packed with needles than Douglas-fir.</p> <p>High latitude of Pacific forests and the height of the canopy allow light to filter in at relatively</p>

	<p>high angles.</p> <p>Understory tree location was poorly correlated with gap location, but shrub location was better correlated with gap location.</p> <p>Several natural gaps were analyzed to determine the gap initiation year and cause, if possible. One gap nearly doubled in size over a 40 year period, with at least 3 separate events causing overstory tree mortality.</p> <p>Trees may take several years to reveal effect of release from competition when a neighbor dies.</p> <p>Highest branch growth of residual trees around experimental gaps (0.35ha) was by the third growing season and was south of center, where diffuse light levels were high, but direct light levels were low.</p> <p>Trees in direct light suffered higher rates of mortality and retained needles for a shorter duration.</p> <p>The northern part of the gap exhibited the greatest change in biological factors measured; this area had the highest soil light and soil temperature levels, and consequently the highest mortality and needle loss on surviving trees.</p>
24	<p>Waldien, D.L., J.P. Hayes and B.E. Wright. 2003. Use of Conifer Stumps in Clearcuts by Bats and Other Vertebrates. NW Sci. 77: 64-71.</p> <p>1 - Very Relevant to Jackson WHMP</p> <p>Inventories of stumps in recent clearcuts found that use was restricted to warm/dry weather, when thermoregulation by bats and amphibians/reptiles would be beneficial.</p> <p>Even bats known to roost in stumps (Long-eared myotis) were less common if snags were at low densities within 2.5 km of the site.</p> <p>Limited snag resources may limit populations of forest-dwelling bats.</p>
139	<p>Walter, S. T. and C. C. Maguire. 2005. Snags, Cavity-Nesting Birds, and Silvicultural Treatments in Western Oregon. JWM 69:1578-1591.</p> <p>1 - Very Relevant to Jackson WHMP</p> <p>Large snags (>50cm dbh & 15m tall) are used disproportionately more than small snags.</p> <p>Experiment included creation of snags in clusters (8-12 snags) and scattered snags in 3 stand treatments: group-selection (33% volume removed in 0.2 to 0.6 ha patches), two-story stands (75% volume removed uniformly, leaving 20-30 scattered mature trees/ha, and clearcuts (with 1.2 green trees/ha retained).</p> <p>Created snags were saw-topped 10-12 years prior to study.</p> <p>19.9% of created snags were noted to have cavity-nesting.</p> <p>Live-topped conifers had low amounts of cavity excavation (7.8%), no active nests and low amounts of sapwood decay.</p> <p>1 active cavity was noted/4.9 created snags.</p> <p>Active cavities were 2.9x more abundant in clearcuts than in group-selection cuts.</p> <p>No difference in number of active nests or evidence of foraging found between clumped and</p>

	<p>scattered snags.</p> <p>Cavity nesting birds did not respond to Silvicultural treatment or snag arrangement, but active cavity numbers did increase from group-selection to 2-story to clearcut stands.</p> <p>Created snags with intact branches had higher incidence of cavity excavation.</p> <p>Snags in 2-story stands had 1.7x more cavities than snags in group-selection stands; no difference was found between group-selection and clearcuts or between 2-story and clearcuts.</p> <p>2-story stands and clearcuts with similar snag densities had more cavity nests, higher species richness, greater species diversity, and more similar communities of cavity-nesting birds compared to group-selection stands. Open canopy stands typically see increased vertical and horizontal structural diversity resulting from increased light input. This results in longer tree crowns and epicormic branching. These structures and snags provide habitat for many insects that are eaten by cavity-nesting birds. ***The low number of foraging events observed on snags indicates that much feeding activity occurs elsewhere.</p> <p>Chainsaw-topped snags began to be used for nesting within 4 to 6 years after creation.</p> <p>Topped snags were consistently more often used for foraging and nesting within the first 9 years due to accelerated decay caused by exposure of the inner wood following crown removal.</p> <p>**Silvicultural treatments resulting in open-canopy stands of mature conifers promote diverse stand structures that support more species and greater abundance of cavity-nesting birds than found in closed-canopy forests with equal snag densities.</p> <p>** A mix of stand conditions is required to meet the needs of all species capable of populating an area.</p>
299	<p>Walter, S.T., Maguire, C.C. 2004. Conifer response to three silvicultural treatments in the Oregon Coast Range foothills. Can. J. For. Res. 34:1967-1978.</p> <p>2 - Somewhat Relevant to Jackson WHMP</p> <p>Field study assessed growth, condition and mortality of residual trees 10 yr after harvest in 85 to 125-yo Douglas-fir stands in OR coast range foothills.</p> <p>3 silvicultural treatments:</p> <p>**Group-selection cut, removed 33% of entire stand volume as patches approx. 0.2-0.8 ha</p> <p>**Two-story regen harvest, removed 75% of volume, 20-30 residual trees/ha</p> <p>**Clearcuts with residual 1.2 trees/ha</p> <p>10 yrs later there was little differentiation in the characteristics of residual trees: tree basal area, diameter and height growth, and crown width and fullness did not differ between treatments.</p> <p>Live crown ratio was largest in clearcuts (0.74), and the proportion of trees with epicormic branching was highest in 2-story stands (35%).</p> <p>45% of trees had more basal area growth in the decade after harvest than in the previous decade.</p> <p>Residual green trees in clearcuts and group-selection stands experienced the highest and lowest percentage mortality, (30.6% vs. 0.2%).</p>
175	<p>Weikel, J.M. and J.P. Hayes. 1999. The Foraging Ecology of Cavity-Nesting Birds in Young Forests of</p>

	<p>the Northern Coast Range of Oregon. Condor 101:58-66.</p> <p>1 - Very Relevant to Jackson WHMP</p> <p>Although woodpeckers sometimes do forage on the same types of snags that they use for nesting (Mannan et al. 1980), there is no information indicating whether management strategies that focus only on nesting habitat would provide adequate foraging habitat to support woodpecker populations. Furthermore, current management strategies rarely consider foraging needs of cavity-nesting species other than woodpeckers.</p> <p>All four species of cavity-nesting bird showed selectivity in use of foraging substrates. Chestnut-backed Chickadees foraged frequently on live trees (Fig. 1), and was the only species observed foraging on shrubs. When foraging on shrubs, they were observed exclusively, and about equally, on vine maple and huckleberry. they selected hardwoods over conifers in relation to their availability (Table 2).</p> <p>Red-breasted Nuthatches foraged mostly on live conifers, but occasionally used snags (Fig. 1), and selected live trees that had larger diameters and fewer crown connections than did randomly chosen live trees (Table 2).</p> <p>The only species to forage substantially on snags and logs was the Hairy Woodpecker (Fig. 1). When foraging on live trees, Hairy Woodpeckers selected deciduous over coniferous trees and selected trees that had larger diameters than did randomly chosen live trees (Table 2).</p> <p>Hairy Woodpeckers selected snags that had larger diameters than did randomly chosen snags, and selected logs that had larger diameters</p> <p>Chestnut-backed Chickadees, Red-breasted Nuthatches, Brown Creepers, and Hairy Woodpeckers showed selectivity in use of foraging substrates. Deciduous trees, large diameter conifers, large diameter heavily decayed snags, and large diameter heavily decayed logs were important components of foraging habitat.</p> <p>Red alder, the most abundant deciduous tree species in our study area, may support a high diversity and abundance of arthropods (Furniss and Carolin 1977, Oboyski 1995). Many of the orders of arthropods found on red alder are important in the diet of adult and nestling Chestnut-backed Chickadees (Lepidoptera, Hymenoptera, and Hemiptera; Beal 1907, Kleintjes and Dahlsten 1992) and adult Hairy Woodpeckers (Coleoptera; Beal 1911, Otvos and Stark 1985). Schimpf and MacMahon (1985) found that arthropod density was higher in canopies of deciduous aspen forests than in canopies of coniferous forests. Because abundance of arthropods may be higher on deciduous than on coniferous trees, deciduous trees within a conifer-dominated landscape likely provide valuable foraging habitat for cavity-nesting birds.</p> <p>Management of nesting resources without regard to foraging resources is probably inadequate to provide habitat for cavity-nesting birds. We contend that in order to effectively manage habitat for cavity-nesting birds, foraging habitat, as well as nesting habitat, should be provided. In young conifer-dominated forests of the Pacific Northwest, patches of hardwoods, large diameter conifers, and large diameter snags and logs should be retained when logging. Legacy snags (large diameter snags from the previous stand) in young forests are especially important resources for cavity-nesting birds both as nesting (Mannan et al. 1980, Lundquist and Mariani 1991) and foraging substrates (Mannan et al. 1980, this study)</p>
256	<p>Wilson, S.M., Carey, A.B. 2000. Legacy retention versus thinning; influences on small mammals. Northwest Science 74(2):131-145.</p> <p>2 - Somewhat Relevant to Jackson WHMP</p> <p>Thinned areas had 1.5x the individual mammals and 1.7x the mammal biomass versus forests that were harvested but retained legacies from the previous forest (live trees, snags, cwd).</p> <p>Thinned stands showed a greater abundance, biomass and diversity of small mammals</p>

	<p>compared to legacy stands, but neither type of management supported the complete small-mammal community found in old growth forests.</p> <p>***authors suggest that combining thinning and legacy retention could provide more benefits than either of the individual strategies tested here.</p>
58	<p>WSU Coop. Extension. 1998. Managing deer on small woodlands. Woodland Fish and Wildlife. WSU Cooper. Extension. MISC0189 Rev. July 1998.</p> <p>1 - Very Relevant to Jackson WHMP</p> <p>Useful management techniques</p>
98	<p>Zarnowitz, J.E. and D.A. Manuwal. 1985. The Effects of Forests Management on Cavity-Nesting Birds in Northwestern WA. J. Wildl. Manage. 49:255-263.</p> <p>1 - Very Relevant to Jackson WHMP</p> <p>Study was conducted on the Olympic National Forest in 1980 but provides recommendations for snag allotments as well as densities of cavity nesting species. Four different successional stages were evaluated for their snag densities and corresponding secondary cavity-nesting species (SCN). Populations of SCN increased with increasing snag densities. Hairy woodpeckers were noted to select Hemlock for their nest sites. When compared to mean dbh of all snags, the average dbh of active nest trees was significantly greater.</p> <p>Densities of primary cavity nesters (PCN) and SCN considered (Vaux's Swift, Northern Flicker, Pileated & Hairy woodpeckers) varied between 4.9 and 9.8 pairs/40ha in 60-120 yr old stands containing roughly 12-60 hard snags/ha. In old growth stands, populations ranged from 5.4 to 6.3/40 ha and contained roughly 30-59 hard snags/ha. Both the density and the species diversity of cavity nesting birds increased as the density of snags increased.</p> <p>The average nest tree was 16m tall, versus the average height of all sampled snags (9.6m).</p> <p>Management recommendations:</p> <ul style="list-style-type: none"> - Retain minimum of 6 hard and 3 soft snags/ha harvested. This is the minimum for maintaining cavity nesting bird populations. - "The bulk of snags" should be greater than 50cm as well as some >23cm and some > 75cm dbh in all successional stages. - A mixture of snag species should be left, especially hemlock and Douglas-fir.
219	<p>Zenner, E.K. 2000. Do residual trees increase structural complexity in Pacific Northwest coniferous forests? Ecol. Appl. 10:800-810</p> <p>2 - Somewhat Relevant to Jackson WHMP</p> <p>Retrospective field study of whether (and how) overstory residual trees were associated with higher structural complexity in stands planted after clearcuts.</p> <p>Naturally regenerated stands, without and without residual trees, that were initiated 55 to 110 yrs prior to study were investigated.</p> <p>Used Structural complexity Index (SCI) to relate components including tree density, tree size variation, species composition with residual trees.</p> <p>Tree diameter variation positively correlated with residuals up to a density of 40 residuals/ha. This retention level appears to promote the development of a shade-tolerant understory without eliminating Douglas-fir from the stand. Tree height variation negatively associated.</p> <p>Stands with intermediate densities of the young cohort and a mixture of about equal proportions of Douglas-fir and shade-tolerant tree spp had the highest structural complexity. East aspect contributed to complexity. On east and north aspects, where shade-tolerant spp more abundant/dominant, thinning, and gap creation and planting of Douglas-fir may be helpful. On south aspects, a greater amount of retained green trees may produce better conditions for shade-tolerant spp.</p>

181	Ziegltrum, G.J. 2004. Efficacy of black bear supplemental feeding to reduce conifer damage in western Washington. J. Wildl. Manage. 68(3):470-474.
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Second Growth / Understory Management

176	<p>Artman, V. L. 2002. Effects of Commercial Thinning on Breeding Bird Populations in Western Hemlock Forests. <i>Am. Midl. Nat.</i> 149:225-232.</p> <p>2 - Somewhat Relevant to Jackson WHMP</p> <p>Compares bird populations and habitat structure in commercially-thinned and unthinned western hemlock stands on a tree farm in Pierce Co. 45 - 55 yo naturally-regenerated western hemlock stands (1270 live tph). CT treatments applied 3 to 5 yr before data collection; removed trees <30 cm dbh, resulting in 466 live tph. Canopy cover reduced from 89% to 73%. Small dead trees (<30 cm) almost as abundant as small live trees in unthinned stands--CT knocked the small dead tree inventory down to 76 tph. Snags >30 cm dbh reduced from 9 to 6 tph (not significantly different).</p> <p>Understory forb, grass and tree seedling components increased significantly post-CT. Moss, fern, shrub no significant difference.</p> <p>CWD volume increased post-CT</p> <p>12 bird species evaluated in this study. Total bird density did not differ between pre- and post-CT. Several bird spp responded positively to this CT: winter wren, dark-eyed junco, red-breasted nuthatch, chestnut-backed chickadee. Unclear why the latter 2 (cavity-nesters) increased post-CT. Similar result for these 2 spp reported by Hagar et al. (1996).</p> <p>Suggests managing with a mosaic of stand conditions (age classes and silvicultural treatments) to satisfy needs of most species. Repeated thinnings may be needed to maintain the mix of habitat conditions through a rotation.</p>
114	<p>Aubry, K.B. 1999. Amphibians in managed, second-growth Douglas-fir forests. <i>J. Wildl. Manage.</i> 64(4):1041-1052</p> <p>2 - Somewhat Relevant to Jackson WHMP</p> <p>Second-growth timber stands managed for timber production had the same amphibian species present in unmanaged Douglas-fir stands. However, higher proportions of northwestern salamanders and western redback salamanders, and much lower proportions of tailed frogs were present in managed forests. No evidence that amphibian abundance was influenced by the amount of CWD, however, CWD in managed stands was not substantially lower than in unmanaged forests for any age classes in this study.</p> <p>The oldest age classes had the highest amphibian species richness, total biomass and total abundance, and higher abundances of ensatina and red-legged frog.</p> <p>Recommends thinning closed-canopy stands and extending rotation in managed stands.</p>
214	<p>Aubry, K.B., Halpern, C.B., Maguire, D.A. 2004. Ecological effects of variable-retention harvests in the northwestern United States: the DEMO study. <i>For. Snow Landsc. Res.</i> 78(1/2):119-137</p> <p>1 - Very Relevant to Jackson WHMP</p> <p>DEMO study (Demonstration of Ecosystem Management Options) conducted in 6 locations in sw OR and WA Douglas-fir stands ranging from 65 to 170 y.o. Data were collected prior to harvest (1994-1996), harvests in 1997-1998, initial post-treatment sampling completed in 2001.</p> <p>6 treatments on 13 ha unit, representing green tree retention systems.</p> <p>**100% retention (no harvest)</p> <p>**75% aggregated retention (all merch trees in three 1-ha circles were harvested--25% of the treatment unit)</p> <p>**40% aggregated retention (five 1-ha circles retained - 40% of the treatment unit - and all merch trees in the surrounding matrix were harvested)</p>

	<p>**40% dispersed retention (dominant and co-dom trees retained in an even distribution throughout the unit. In each block, the basal area retained was equal to that retained in the 5 patches of the corresponding 40% aggregated-retention treatment)</p> <p>**15% aggregated retention (two 1-ha circles were retained - 15% of the treatment unit - and all merch trees in the surrounding matrix were harvested.</p> <p>**15% dispersed retention (dominant and co-dom trees retained in an even distribution throughout the treatment unit. In each block, the basal area retained was equal to that retained in the two patches of the corresponding 15% aggregated-retention treatment.)</p> <p>Post-harvest treatment:</p> <p>**6.5 snags/ha created in all harvested areas</p> <p>**Pre-existing CWD retained, but no prescription implemented to create additional material.</p> <p>**Reforestation (mix of spp) to achieve min. stocking of 312 tph at 5 yrs post-harvest</p> <p>Response variables</p> <p>**overstory and understory vegetation - will examine effects of GTR on forest structure and composition, and quantify veg changes to aid in understanding responses of associated organisms and processes.</p> <p>**ectomycorrhizal fungi</p> <p>**canopy arthropods</p> <p>**amphibians and forest-floor small mammals</p> <p>**bats</p> <p>**breeding birds</p> <p>Pre-publication summaries:</p> <p>Overstory and understory vegetation. Most groups of forest understory plants declined in abundance and richness more at 15 than at 40% retention. Changes within 1-ha aggregates were small on average, and declines in adjacent harvested areas were greater than those in the corresponding dispersed treatments. Forest herbs declined on the edges of the 1-ha aggregates. Late-seral herbs more frequently extirpated from harvested plots in the aggregated treatments than from plots in the dispersed treatments.</p> <p>Salamanders. Little evidence that level or pattern of retention strongly influenced salamander populations during the first few yrs post-harvest. Within aggregated-retention treatments, salamanders more frequently captured in uncut than in cut areas. Salamanders most abundant in areas where CWD and/or herb cover were high.</p> <p>Small mammals. Pattern of retention did not have consistently strong effects on small mammal abundance or community comp. Initial results indicate that 1-ha aggregates may function as short-term refuges for several interior-forest spp: red-backed voles.</p> <p>Bats. Variable-retention treatments created forest openings/reduce canopy density and increased use by some bat spp--perhaps concentrated their use in these openings. Furthermore, greatest impact on bat populations is probably loss of large trees and snags roosting habitat.</p> <p>Breeding birds. Variable responses depending on the species. In general, birds that feed or nest in tree canopy or feed in bark decreased at greater harvest levels, whereas spp associated with forest-edge or open habitats increased.</p> <p>Second round of post-treatment veg sampling scheduled for 2003 and 2004.</p> <p>For summary reports from individual studies see http://www.cfr.washington.edu.research.demo/research/r_invert.htm</p> <p>IUFRO meeting on Innovative Experiments for Sustainable forestry in Aug. 2004 in Portland</p>
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235	<p>Aubry, K.B., M.P. Amaranthus, J. D. White et al. 1999. Evaluating the Effects of Varying Levels and Patterns of Green-tree Retention: Experimental Design of the DEMO Study. Northwest Sci. 73: 12-26.</p> <p>1 - Very Relevant to Jackson WHMP</p> <p>Aggregated retention is thought to be more effective at maintaining a broad array of structural elements, such as multiple canopy layers and understory vegetation, and snags of various sizes and decay classes that would not be possible in dispersed retention systems.</p> <p>Intact patches of habitat also act as refugia for organisms that will recolonize the harvest unit.</p> <p>Study set-up:</p> <p>*Snags that were deemed safe to work around were retained.</p> <p>*6.5 additional dominant/co-dominant green trees/ha were retained for snag creation.</p>
322	<p>Bailey, J.D., Tappeiner, J.C. 1998. Effects of thinning on structural development in 40- to 100-year-old Douglas-fir stands in western Oregon. For. Ecol. And Management 108:99-113.</p> <p>2 - Somewhat Relevant to Jackson WHMP</p> <p>Retrospective study of stands that had been thinned for timber production 10-24 years before the study. At the time of this study, thinned stands had a wide range of density (mean 173 tpa, range 72-346), basal area (mean m²/ac, range 20-58) and relative density (mean 0.37, range 0.23-0.60).</p> <p>Conclusions: Thinning young Douglas-fir stands will hasten the development of multistory stands by recruitment of conifer regeneration in the understory as well as by enabling the survival of small overstory trees and growth of advanced understory regeneration. Thinning will also help develop the shrub layer by increasing tall shrub stem density and cover of some low shrubs.</p>
275	<p>Bailey, J.D., Mayrsohn, C., Doescher, P.S., St. Pierre, El., Tappeiner, J.C. 1998. Understory vegetation in old and young Douglas-fir forests of western Oregon. For. Ecol. And Manage. 112:289-302.</p> <p>3 - Not Relevant to Jackson WHMP</p> <p>Field study of thinned and unthinned Douglas-fir stands in western OR. Stands had regenerated naturally after timber harvest, 40 - 70 yrs before thinning. Commercial thinning had occurred 10-24 yrs previously, with 8-60% of volume removed from below with intent to homogenize tree spacing. There were also undisturbed old-growth Douglas-fir reference sites.</p> <p>Total herb cover greater in thinned (25% cover) than unthinned (13%) or old-growth stands (15%). Species richness greater in thinned (137) than in unthinned (114) and old-growth (91). Part of increased richness caused by exotic spp in thinned stands, but these also had move native grass and nitrogen-fixing spp.</p> <p>Ordination of herbaceous community data showed there were much stronger differences among sites than among stand-types; This lack of difference among stand-types demonstrates the resiliency of herbaceous communities to disturbance associated with past and current forest management.</p>
115	<p>BC Ministry of Environment and BC Ministry of Forests. 1993. Guidelines for maintaining biodiversity during juvenile spacing. BC Environment. Canada-British Columbia Forest Resource Development Agreement FRDA II.VI</p> <p>2 - Somewhat Relevant to Jackson WHMP</p> <p>General basic descriptions of habitat features associated with biodiversity, with a few useful concepts for restocking at the stand level:</p> <p>Retain 5-10 live wildlife trees/hectare, 3 of which should be within the upper 10% of the diameter range of the stand</p>

	<p>Retain wildlife trees in small groups, at the edge of surrounding forest to avoid safety and operational conflicts. Isolated trees more susceptible to windthrow, offer less cover for wildlife.</p> <p>All stumps greater than 25 cm diameter, less than 3 m in height should be retained for woodpecker foraging.</p> <p>Cut shrubs taller than 3 m to promote coppicing and improve browse.</p> <p>Leave pre-existing wildlife trails unobstructed through directional falling and/or slash removal.</p> <p>Wider or patchy spacing in areas adjacent to water to encourage growth of woody forage species. Patchy spacing with some areas of higher density, will provide cover.</p> <p>Wider spacing adjacent to deciduous patches to promote forage species.</p> <p>Examples of contract specs</p>
204	<p>Beach, E.W., Halpern, C.B. 2001. Controls on conifer regeneration in managed riparian forests: effects of seed source, substrate, and vegetation. <i>Can. J. For. Res.</i> 31(3):471-482</p> <p>2 - Somewhat Relevant to Jackson WHMP</p> <p>Field study in western WA testing hypothesis that seed availability rather than competitive interactions shapes patterns of conifer regen in managed riparian forests.</p> <p>Frequency and density of conifer regen were significantly greater within 100 m of remnant forest patches than at greater distances.. Where seed sources were present, regen positively associated with CWD and negatively associated with fine litter. Regen most abundant in plots with <10% herb or shrub layer. No relationship detected between regen density and overstory conifer or hardwood cover. Results suggest that in managed forests, conifer regen is largely limited by seed availability and only secondarily by competitive interactions or substrate conditions. Suggest GTR as an effective tool for increasing conifer regen in riparian zone.</p>
48	<p>Beggs, L.R. 2004. Vegetation response following thinning in young Douglas-fir forests of western Oregon: can thinning accelerate development of late-successional structure and composition? Corvallis, OR. Oregon State University. Master's thesis.95p.</p> <p>1 - Very Relevant to Jackson WHMP</p> <p>Field study that concludes that some types of thinning can place young managed stands on an accelerated trajectory toward late-successional attributes such as large diameter trees. 5 to 7 yrs following light (standard commercial thinning) thinning, canopy cover no longer differed from Control.</p> <p>Thinnings resulted in initial declines of bryophytes, tall shrubs and low shrubs followed by subsequent recovery and growth. Release of early seral-stage herbs by 5-7 yrs post-treatment. The addition of gaps generated plant assemblages that differed across the gradient from the gap to the thinned forest matrix. Concludes that thinning with gaps can hasten late-successional understory development.</p>
321	<p>Beggs, L.R., Puettmann, K.J., Tucker, G.F. 2005. Vegetation response to alternative thinning treatments in young Douglas-fir stands. In Peterson, C.E., Maguire, D.A., eds. <i>Balancing Ecosystem values: innovative experiments for sustainable forestry</i>. Gen. Tech. Rep. PNW-GTR-635. USDA Forest Service, Portland, OR p. 243-248.</p> <p>2 - Somewhat Relevant to Jackson WHMP</p> <p>Part of the Young Stand Thinning and Diversity Study.</p> <p>4 replications of 4 thinning treatments initiated in 1995.(avg. 30 ha each) in 30- to 50-yo Douglas fir stands.</p> <p>Uncut control, heavy thin, light thin, and a light thin with gaps.</p>

	<p>Unlike traditional CT, this study maintained overstory diversity by specifically retaining hardwoods and conifer spp other than Douglas-fir.</p> <p>Results of vegetation data indicate that only the heavy thinning maintained open canopies for multiple years and accelerated development of large trees. Thinning did not result in higher mortality rates, but decreased density-related mortality of Douglas-fir. Mortality was low for nondominant overstory trees that were retained. Vertical canopy structure did not respond immediately to thinning.</p>
231	<p>Canham, C.D., J.S. Denslow, W.J. Platt, J.R. Runkle, T.A. Spies and P. S. White. 1990. Light Regimes Beneath Closed Canopies and Tree-Fall Gaps in temperate and Tropical Forests. <i>Can. J. For. Res.</i> 20:620-631.</p> <p>2 - Somewhat Relevant to Jackson WHMP</p> <p>Light penetration into the forest and its associated effects can extend considerable distances beyond the edges of canopy gaps.</p> <p>PAR = photosynthetically active radiation</p> <p>During the course of the growing season, both total open-site PAR and total closed-canopy PAR are roughly evenly split between diffuse and direct radiation.</p>
56	<p>Carey, A.B. 2003. Biocomplexity and restoration of biodiversity in temperate coniferous forest: inducing spatial heterogeneity with variable-density thinning. <i>Forestry</i>, 76(2): 127-136</p> <p>See #27</p> <p>Summarizes results of experiments using VDT initiated in 1991 se of Olympia.</p> <p>Second-growth stands conventionally thinned twice to final density of 225 - 236 tpa 10 yrs previously. Other stands had old growth legacy green trees and snags, stumps and CWD. VDT thinning assigned to stands; controls provided. Used relative density (RD) to determine level of thinning. Description of thinning treatments.</p> <p>Conventional thinning produced timber stands with rich understory dominated by clonal natives and exotics. Shade-tolerant trees lacking.</p> <p>Legacy forests had depauperate understory and low abundances of small mammals and winter birds. Thus, neither historical management regime had placed stands on a course to produce the complexity and diversity of old growth forests. The experimental treatments produced mosaics of increased diversity and abundance of native spp in <5 yrs, and ephemerally increased exotics. Underplanting is leading to increased spatial heterogeneity. The legacy stands, with VDT, appear to be on a better course toward desired biocomplexity.</p>
27	<p>Carey, A.B., Curtis, R.O. 1996. Conservation of biodiversity: a useful paradigm for forest ecosystem management. <i>Wildl. Soc. Bull.</i> 24(4):610-620</p> <p>1 - Very Relevant to Jackson WHMP</p> <p>Proposes stages of forest ecosystem development in the Western Hemlock zone:</p> <ul style="list-style-type: none"> Ecosystem initiation Competitive exclusion Understory reinitiation Developed understory Botanically diverse Niche diversification Fully functional (managed) Old-growth <p>Compares them with Brown (1985) stages, e.g. Competitive exclusion is similar to closed sapling-pole-sawtimber, and Developed understory is similar to large sawtimber. Carey's descriptions are useful because they describe benefits to wildlife in addition to describing canopy species size/density. He proposes biodiversity treatments for each stage, including variable density thinning with and without CWD and snag augmentation.</p>

	<p>Management foundations of the biodiversity pathway:</p> <ol style="list-style-type: none"> 1. Conserve biological legacies during harvest and regeneration by avoiding intensive site preparation and burning wherever these are not essential to establishment of regeneration or maintenance of forest health. Legacies include soil organic matter, litter, CWD, snags, mosses, lichens, forbs, ferns, shrubs, live trees of the preceding forest, and mycorrhizal fungi. 2. Plant Douglas-fir at wide spacing to insure representation of this species, while providing for natural or artificial regeneration of hemlock, red cedar, grand fir, western white pine. Concurrent regeneration of red alder, bigleaf maple, evergreen hardwoods is desirable in limited amounts. 3. Minimize area and time in the competitive exclusion stage through PCT and VDT (heavier than conventional commercial thinning). 4. Ensure diversity and niche diversification in later stages through subsequent thinnings with CWD augmentation. 5. Use extended rotations (80-130 yrs) on a significant part of the land base. Harvesting or regeneration systems could range from clearcutting to group selection or individual tree selection to none, depending on local conditions and the goals for the land manager. <p>Minimize site prep to reduce invasion by excessive red alder. Control dense shrub layers as needed to secure conifer establishment; in closed-canopy second growth conifer stands, use biodiversity thinnings to maintain or restore diversity.</p> <p>Suggests using 2+ densities in the initial VDT. E.g., retain 309 tpa and 185 tpa in a 2:1 ratio on a 0.2 ha scale in a 30- to 50-year-old stand of 10- to 50-cm dbh trees.</p> <p>Suggests 2 additional VDTs to leave CWD to meet target of 15% cover on the forest floor, maintain understory. CWD size range 10 to 100-cm dbh..</p> <p>Suggests the biodiversity thinnings will produce approximately the same long-term wood production resulting from conventional rotation length, but cost is the reduction in present net value associated with extended rotations.</p>
77	<p>Chan, S.S., Maas-Hebner, K.G., Emmingham, W.H. 1999. Commercial thinning and underplanting to increase structural and species diversity in young managed Douglas-fir stands. Proc. Soc. Am. Foresters. 1999 National Convention. Sept. 11-15, 1999. Portland, OR</p> <p>2 - Somewhat Relevant to Jackson WHMP</p> <p>Field experiment to examine the effects of thinning and underplanting on the structure of young (30 - 35 y.o.) Douglas-fir plantations in the Oregon coast range. Examined consequences of underplanting or not underplanting, response of 8 native tree spp to overstory density, dynamics of natural regen.</p> <p>4 thinning treatments:</p> <ul style="list-style-type: none"> *Uncut control (220 tpa) * Conventional commercial thin (199 tpa) *Wide thin (60 tpa) *Very wide thin (30 tpa) <p>5 yrs post-treatment:</p> <ul style="list-style-type: none"> *cover and height of most understory plant spp increased *Height of vine maple reduced by thinning. It appears to take at least 3 yrs for maples to recover from harvest damage. *Growth of Douglas-fir and western hemlock seedlings greatest in the heaviest thinnings, while all seedlings planted in unthinned stands died. *Sitka spruce, western redcedar, grand fir, red alder seedlings showed greater growth rates in widely thinned stands and failed to establish in unthinned stands. *Natural regen of conifers less than expected, probably due to low cone production in overstory. Abundance and vigor of these seedlings increased with thinning intensity. No

	<p>natural regen conifers in unthinned stands. 4 to 7x as many naturally regen conifer seedlings present in the wide and very wide thinnings.</p> <p>*Rapid canopy development in trees in 5th yr in conventionally thinned treatments. Light levels in conventional thinnings declined from 20% (of unthinned light level?) after thinning to 12% after 5 yrs. Without subsequent thinning the canopy closure may hinder understory development. Less precipitous decline in wider thinnings.</p> <p>*Discussion of soil disturbance--cable yarding reduced soil disturbance but may select against natural regen of spp that favor mineral soil.</p> <p>*Soil temp during 5th yr showed that soil in convention thinning was warmed than in unthinned stands by 1 - 2 degrees. Soil temp in wider thinnings was 2 to 6 degrees warmed than unthinned stands.</p> <p>* Recommend mosaic of small openings, variable spaced thinning to wider spacings, or repeated thinning entries to promote late-successional stand characteristics.</p> <p>Stands will be re-measured at 8 and 13 yrs post-treatment.</p>
191	<p>Creighton, J.H. 2000. Controlling black bear damage to conifer stands: does the supplemental feeding program work? Forest Stewardship Notes 9(2):9-10.</p>
25	<p>Gray, A.N., Spies, T.A. 1996. Gap size, within-gap position and canopy structure effects on conifer seedling establishment. J.Ecology 84:635-645.</p> <p>1 - Very Relevant to Jackson WHMP</p> <p>Portions of large gaps with direct exposure to the sun had relatively low seedling establishment, particularly for Hemlock. All species were most abundant in the shaded portions of gaps.</p> <p>An increase in gap size corresponded to an increase in seedling size, being the greatest at gap centers.</p> <p>Douglas fir seedling growth was relatively low except in the largest gaps. Hemlock growth increased dramatically with gap size, and silver fir responded the least to gap size.</p> <p>Created gaps may help to accelerate the development of multiple canopy layers.</p> <p>Seedling density appears better related to gap age than to gap size.</p> <p>Both Hemlock and Silver fir can survive for many decades with little growth in shaded forests, and resume growth following a disturbance and concomitant increase in light levels.</p> <p>Contrary to common opinion, Douglas fir can germinate in shade or become established on intact forest floor.</p>
26	<p>Gray, A.N., Spies, T.A. 1997. Microsite controls on tree seedling establishment in conifer forest canopy gaps. Ecology 78(8):2458-2473.</p> <p>1 - Very Relevant to Jackson WHMP</p> <p>Species composition within gaps is likely determined by more than size and shape of the gap; fine scale environmental factors may also be important.</p> <p>Gap sizes were determined by gap diameter:tree height ratios, and were classified as 0.2, 0.4, 0.6 & 1.0</p> <p>Douglas-fir reproduces best on mineral soil in high-light conditions. Hemlock is shade tolerant, but appears to be so sensitive to competition from other understory vegetation while in the seedling stage that successful regeneration is usually limited to growing on decaying Douglas-fir logs.</p> <p>Silver fir is also shade tolerant, but is sensitive to both overstory and understory canopy density.</p> <p>*** Many gaps were found to be devoid of tree saplings more than 50 years after gap formation.</p>

	<p>For seedling establishment, gap size was marginally significant. Silver fir and Hemlock seedling establishment was greater in the 0.2 and 0.4 gaps than in controls and 1.0 gaps. Hemlock establishment in the 1.0 gaps were significantly lower than the other species. Seedling size increased with gap size. Particularly for silver fir, seedling establishment in the 1.0 gaps was greatest in 90% shade. Seedling survival for both Douglas-fir and hemlock was highest on decayed wood. Douglas fir tended to survive best in shady portions of the sunniest gap area (i.e. north edge) and in the more open portions of the smaller, darker gaps (i.e. south edge). The advantage that hemlock incurs from growing on decaying wood appears to decrease with gap size.</p>
45	<p>Gray, A.N.. 2000. Adaptive ecosystem management in the Pacific Northwest: a case study from coastal Oregon. Cons. Ecol. 4(2):6.</p>
216	<p>Halpern, C.B., McKenzie, D., Evans, S.A., Maguire, D.A. 2005. Initial responses of forest understories to varying levels and patterns of green-tree retention. Ecol. Appl. 15:175-195. 1 - Very Relevant to Jackson WHMP Study is part of DEMO project. Initial (1-2 yr) responses of understory plants to GTR at six locations in western OR and WA. See #214 for details of experimental treatments.</p> <p>Magnitude of change in understory composition was consistently larger at 15% than at 40% retention; pattern of retention had little effect. Despite major changes in vegetation structure, early-seral herbs contributed little to plant abundance and richness in most treatments. For many forest understory groups, declines in abundance or richness were significantly greater at 15% than at 40% retention. Late-seral herbs had more frequent extirpations from plots within harvested portions of aggregated treatments than from dispersed treatments.</p> <p>Initial responses of forest understories to GTR are mediated in part by associated patterns of disturbance and slash accumulation that differ significantly with level and pattern of retention. These are short-term responses, and future sampling will help understand how canopy structure affects patterns of understory composition and structure.</p>
217	<p>Halpern, C., McKenzie, D., Evans, S., Saracco, J., Maguire, D., Halaj, J. 2005. Vegetation responses to varying levels and patterns of overstory retention: early results of the DEMO experiment. In. Peterson, C.E., Macuire, D.A., editors. Balancing ecosystem values: innovative experiments for sustainable forestry. Proceedings of a conference. Gen.Tech. Rep. PNW-GTR-635. USDA Forest Service. Pp. 357-359.</p> <p>2 - Somewhat Relevant to Jackson WHMP DEMO study early results. See #214 for experimental design. Focus on post-harvest mortality of trees and responses of two groups of understory plants: late-seral herbs nad ground-layer bryophytes.</p> <p>Focus on 5 of the 6 treatments: control, and four treatments that contrast level of retention (40 vs. 15% of original basal area) and appregated vs. dispersed distribution.</p> <p>Tree mortality: cumulative mortality significantly greater at 15% than at 40% retention. At both levels of retention, aggregation of trees significantly reduced mortaltiy. Mortality of co-dominants greater at lower levels of retention, especially in dispersed treatments. Suppressed trees had high mortality in dispersed than in aggregated treatments. Wind damage particularly common in the 15% dispersed treatment.</p> <p>1. Short-term, forest aggregates of 1-ha are fairly stable 2. At low retention levels, dispersed patterns susceptible to logging and wind damage, leading</p>

	<p>to increased mortality, even among co-doms.</p> <p>Understory:</p> <p>Declines in spp frequency and richness, and changes in spp comp significantly greater at lower level of retention. Pattern of retention had little effect on understory response. This result attributed to extremes in response within the aggregated treatments: post-harvest changes small within the aggregates, but declines in adjacent harvest areas were large and generally greater than those in dispersed treatments. Late-seral herbs particularly sensitive to these effects, more frequent extirpations from harvested portions of aggregated treatments. These initial responses to harvest consistent with patterns of ground disturbance and slash accumulation which varied among the treatments. As effects of disturbance diminish over time, expect that variation in overstory will play more important role in understory recovery.</p> <p>Higher retention reduced wind throw and loss of late-seral herbaceous spp. Responses to pattern of retention were mixed: tree mortality reduced in aggregated treatments, but benefit of aggregated retention for understory plants limited to forest aggregates. In adjacent harvest areas, spp showed greater declines than in dispersed treatment areas. Forest aggregates serve as refugia for plant spp that are sensitive to disturbance or require deep shade or moist substrates. Long-term may be sources of dispersal to adjacent harvest areas.</p> <p>These functions may be compromised by edge effects, but suggest that patches of 1-ha sufficiently large to maintain viable populations of most spp.</p>
213	<p>Halpern, C.B., Spies, T.A. 1995. Plant species diversity in the natural and managed forests of the Pacific Northwest. <i>Ecol. Appl.</i> 5(4):913-934.</p> <p>2 - Somewhat Relevant to Jackson WHMP</p> <p>Data from permanent plots and chronosequence studies in managed and unmanaged forests of western OR and WA. Describes understory response to harvest. Post-harvest practices alter natural successional processes may influence long-term patterns of diversity and species occurrence.</p> <p>Early succession in old growth Douglas-fir forests suggest that changes in understory diversity are fairly short-lived following clearcut and slash burning. Most vascular plant populations recover to original levels prior to canopy closure. Diversity may remain depressed for more than two decades on severely burned sites; some species experience local extinction.</p> <p>Evidence of the effects of post-harvest practices on vascular plant diversity limited by absence of studies in older, managed forests. Chronosequence studies of natural forest stands indicate that, following canopy closure, vascular plant species diversity tends to increase with time, peaking in old growth. Few understory species are restricted to any stage of stand development, but many species differ in their abundance among stages. Most showed greatest abundance in old growth. Temporal changes in levels of resources (shade), changes in spatial distrib. of resources, and species' sensitivity to fire and slow rates of reestablishment may drive these trends in natural stand development.</p> <p>Silvicultural prescriptions that maintain or foster spatial and temporal diversity of resources and environments will be most effective in maintaining plant species diversity. It may be necessary to manage some stands on long rotations (150-300 yr) to maintain understory species with slow recovery rate after disturbance.</p>
264	<p>Hanley, T.A. 2005. Potential management of young-growth stands for understory vegetation and wildlife habitat in southeastern Alaska. <i>Landscape and Urban Planning</i> 74(1-3):95-112.</p> <p>2 - Somewhat Relevant to Jackson WHMP</p> <p>Review article on understory vegetation response to logging and silviculture treatments in se Alaska.</p>

	<p>Conventional wisdom:</p> <ul style="list-style-type: none"> *Understory vegetation increases dramatically immediately after logging but decreases to near-zero as stands attain conifer canopy closure. *Depauperate understories may persist for >100 yrs. *Understory response to thinning of even-aged stands is mainly by dominant shrubs and is short-live. *response by herbs, especially forbs, is slight. *Western hemlock identified as potential long-lived, second layer, understory dominant in stands thinned to wide spacing. <p>Recent studies qualify these findings:</p> <ul style="list-style-type: none"> *Red alder-conifer, even-aged stands produce species-rich and high-biomass understories comparable to those of old growth forests and much greater than similar-age pure conifer stands. *Commercial thinning of older even-age stands may result in much greater understory biomass, including forbs, but time requirements might be longer than previously thought. Plant spp differ in their ability to germinate and establish, and in their growth rates in relation to light; therefore, understory spp response to thinning may be the result of differential time lags in response to light, differential species productivity in relation to light, and dynamics of change in the understory light environment. *Extrapolation of data from small scales of research plots to large scales of timber-management stands tends to greatly overestimate stand homogeneity, and underestimate understory biomass of even-aged conifer stands. <p>Cites ongoing experiments with dwarf dogwood, Vaccinium, salmonberry and devil's club under different light regimes.</p> <p>"Engineering" understory objectives:</p> <ul style="list-style-type: none"> *Select a few major understory spp and study their autecology. *Understand light, temperature and soil requirements for germination and establishment. *Understand each spp' requirements for light and nutrients for growth and reproduction *Understand how silviculture treatments change the understory light and soil environments, and how conditions change with time post-treatment. <p>Design silviculture prescription to creation desired conditions (e.g. light levels). Hypothetical example: If forbs respond most quickly to increased light, and western hemlock respond most slowly, we might want a prescription that begins with a relatively light-starved environment and then opens the overstory canopy abruptly. If hemlock requires more light for growth than forbs, might want the overstory canopy to fill in before the hemlock seedlings can begin shading out the forbs. Once desired understory is established, maintain a light environment sufficient for forbs but insufficient for hemlock.</p>
310	<p>Harrington, C.A., Roberts, S.D., Brodie, L.C. 2005. In: Peterson, C.D., Maguire, D.A., eds. Balancing ecosystem values: innovative experiments for sustainable forests. Gen. Tech. Rep. PNW-GTR-635. Portland, OR: USDA Forest Service, Pac. NW Res. Stn. P. 97-106.</p> <p>2 - Somewhat Relevant to Jackson WHMP</p> <p>Olympic Habitat Development Study initiated in 1994, evaluates where management of 35- to 7 y.o. stands could accelerate late-successional characteristics. Variable-density thinning involving complex prescription: Skips = untreated patches and Gaps + stand openings embedded in a thinned matrix. Skips about 0.1 to 0.3 ha and covered 10% of plot area. Skips preserved large snags, with max. 1 skip per about 2.0 ha. Gaps 0.04 to 0.05 ha, covered 15% of the plot area. Used existing root-rot pockets. Matrix covered 75% of treatment area, thinned by removed 25% of basal area, mostly from below.</p> <p>Assessed tree damage, mostly windthrow, 5-yr tree growth, 3-yr vegetation development.</p>

	<p>Tree growth responded positively to thinning. Understory vegetation responded to thinning with increased cover and number of herb spp in thinned areas and created gaps. Introduced spp most prevalent in the thinned and gap subtreatments vs skips or control plots. All introduced spp were herbaceous except Him. Blackberry. Shrub response slower than herb response and more variable. Shrubs previously present on stands persisted despite damage, and are slowly increasing. Cover of mosses and liverworts greatest in undisturbed areas. Thinning rx was operationally feasible.</p>
245	<p>Harrington, T.B. 2006. Silvicultural guidelines for creating and managing wildlife habitat in westside production forests. In Harrington, T.B., G.E. Nicholas, tech. eds. Managing for wildlife habitat in west-side production forests. Gen. Tech. Rep. PNW-GTR-695. Portland, OR:USDA Forest Service, Pac. NW Res. Stn. Pp. 49-60.</p> <p>1 - Very Relevant to Jackson WHMP</p> <p>Designing New Stands</p> <p>Pre-treatment planning required to identify appropriate treatment intensity, to retain existing structural elements, or provide conditions for development of new structural elements. Specific habitat features that can be retained or created:</p> <ul style="list-style-type: none"> **forage (mast, browse, or grazing) spp **nest sites **snags and green trees **shrub cover **CWD <p>Areas in harvest unit can be designated for wood production, combination of wood production and wildlife habitat, and habitat only, to avoid conflicting treatments.</p> <p>Cites WA DNR (2006) recommendations for snags:</p> <ul style="list-style-type: none"> **Locate snags away from trails, roads, buildings, etc. **Conifer snags last longer than hardwood snags; selected trees should have a stem diameter of at least 14 in to provide nest sites and for increased longevity. **Trees should be topped or girdled at or above the first whorl of branches, at least 14 ft above ground and ideally much higher. Smaller trees or stumps at least 3 ft tall may be useful for some cavity nesters **A jagged top decays faster **Artificial cavities, (6 in deep X 4 in high) accelerate decay in new snags **Large branches (2 ft long or more) provide foraging habitat **Roosting slits (angled upward at least 8 in deep and 8 in wide) are used by bats and some birds <p>Establishing Understory Conifers</p> <p>If goal is to manage understory conifers as a second story for habitat (and ultimately crop trees), recommends relatively low overstory. Overstory density should not exceed 20% of full stocking.</p> <p>Reduction in overstory density can result in excessive conifer regen. Can reduce regen via moderate soil disturbance during timber harvest or a subsequent pre-commercial thinning</p> <p>Promoting Understory Vegetation</p> <p>Thinning combined with moderate soil disturbance creates germination substrates for seedling regen of woody and herbaceous spp. Thinning Douglas-fir stands is followed by increases in seedling germination of salal, vine maple, huckleberry, tanoak, bigleaf maple, red alder, salmonberry, Pacific madrone. However, development of shrub cover and wildlife forage occurs much more rapidly from sprouts, which is the preferred method of regeneration.</p> <p>Thinning intensity and pattern influence spatial distribution of woody debris and soil</p>

disturbance. In the DEMO study, depth and cover of debris were greater at the highest thinning intensity and in aggregated vs. dispersed retentions of overstory trees (Halpern and McKenzie 2001).

Using thinning to create old-forest structure

**Retain large trees from previous stand, especially those with large limbs, cavities and rough bark

**Retain minor spp including Sitka spruce Engelmann spruce, yew

**Create seedbeds for establishment of understory plants, via soil disturbance (e.g. skidding of logs)

**Control understory competition when it becomes excessive. A dense understory of shrubs like salal, vine maple, salmonberry, huckleberry or blackberry; hardwoods like bigleaf maple, can interfere with seedling establishment of conifers and otherspp. In these cases, it may be necessary to control shrubs and hardwoods, and plant conifer seedlings to establish a multi-storied stand.

**Manage some trees or parts of stands at low density, via thinning around selected trees in order to provide space, maintain large crowns and continue rapid diameter growth.

**Use thinning to favor patches of regeneration. Thinning can be concentrated around patches of advanced tree regen to facilitate development of multi-storied stands.

**Allocate trees for production of snags and CWD See DecAID guidelines to produce appropriate abundances and sizes of woody debris

**Relatively dense overstories favor some herbaceous spp. Maintaining dense patches of overstory trees or excessive conifer regen may retard establishment of a dense shrub cover, and provide sites for late-seral herbaceous plants (Lindh 2005).

**Large (>40 in diameter) old (>200 yrs) trees will respond positively to thinning.

**Create space for hardwoods. Reduce conifer density around hardwood to maintain full vigorous crowns. Recommends heavy thinning around 0.25 to 0.6-ac patches of hardwoods.

Opportunities to do these things occur sporadically in stands, therefore, density will be spatially variable. E.G. if the goal is to grow 30 large trees/ac, the range might be >40 trees in some areas and <10 trees elsewhere, with an avg. of 30 trees over an area of 5 to 10 ac.

Information needs for planning stand development:

**Sizes, densities and spp comp of large overstory trees and second-story trees needed to produce multi-storied stands.

**Stand density or gap size needed to grow understory trees

**Sizes and densities of existing snags and CWD

**Effects of snow, wind, insects and pathogens on tree mortality and the associated production of snags, logs on the forest floor, and cavities.

Tree and stand responses to thinning.

At the stand level, thinning reduces competition for light, water and nutrients, thereby increasing the growth of overstory trees and the abundance of understory plants.

A major response of trees to thinning is increase in crown size. Tree crown height increases as lower branches survive and height growth continues. As crown length increases, stem diameter increases on the lower part of the stem: the tree's stem becomes more tapered and more resistance to windthrow or stem breakage. An increase in diameter may occur within 3 to 5 yrs. Epicormic branching in Douglas-fir produces fan-like branches using for roosting by birds and rodents.

Caveats.

Treating stands once with a single heavy thinning might create a dense shrub (or conifer) understory with low diversity. Thinning around hardwoods would then be necessary.

Suggests conducting light thinning to begin the process and develop options for future development. E.g. the initial treatment might enable reprod in the understory and begin

	<p>development of large trees. A 2nd thinning would release the understory trees and provide for continued growth of large trees.</p> <p>Thinning leads quickly to understory density, and conifer regen. Immediate benefits to wildlife. Other old forest attributes, like large cavities, nesting platforms on large limbs, or high abundance of CWD, will take decades to develop.</p>
80	<p>Hayes, J.P., Chan, S.S., Emmingham, W.H. (and others). 1997. Wildlife response to thinning young forests in the Pacific Northwest. <i>J. Forestry</i> 95(8):28-33.</p> <p>2 - Somewhat Relevant to Jackson WHMP</p> <p>Review article on enhancing stand structure in second growth stands.</p> <ul style="list-style-type: none"> ---Promote large live trees. Thinning results in increased diameter growth -- Promote large crowns to provide better habitat for birds, red tree voles. ---Thinning in 20- to 50-year-old stands promotes development of large crowns on dominant and codom trees if done relatively early in a stand's development. See Marshall 1992. ---Promote large branches. They develop only on widely spaced trees or on trees adjacent to gaps or openings. ---Deep fissures in the bark, typical of large-diameter Douglas fir. No silvicultural techniques available to accomplish this, but could create desirable habitat. ---Promote large snags and down trees. No numbers provided ---Multilayered canopies. No specifics ---Understory vegetation. Response of understory veg to thinning depends on initial density, species composition, vigor of understory plants before thinning, seed sources and bud banks, thinning intensity, soil disturbance; however, sunlight is the primary factor. Thinning to moderate densities in closed-canopy stands stimulates modest and temporary development of understory veg (e.g. RD 25); heavier thinning or multiple entries favors the establishment and growth of conifer seedlings, shrubs and hardwoods (e.g. RD 20). <p>Timing: Thinning stands before age 15 will encourage wind firmness and large crowns. Thinning dense stands in the stem exclusion stage increases potential for windthrow, although thinning in stages can minimize the problem. Repeated thinning in later stages (age 70 to 100) may lead to stands resembling shelterwood, with understory beneath a few large trees.</p> <p>Relative Density: The actual density of trees relative to the theoretical maximum density possible for the site, on a scale of 0 to 100.</p> <p>At RD>55m suppression mortality happens</p> <p>Stands typically thinned to RD 35 for timber production, and allowed to grow back to RD 55 before final harvest or additional thinning.</p> <p>Thinning to >RD 35 is a light thinning.</p> <p>Thinning to RD 25 or less (heavy thinning) and thinning again when the stand grows to RD 45 promotes understory development and vertical diversity.</p> <p>RD diagram (see supportive link) predicts stands can have about 20 healthy, 50-inch dbh trees per acre; stands at this density are likely to have a rich understory. Stands with 40 50-inch dbh douglas-fir trees per acre are likely to be in poor condition and have little understory; trees at this density will also attain that size relatively slowly. Need empirical evidence to confirm this.</p>
84	<p>Johnson, D.H., O'Neil, T.A., managing dirs. 2001. <i>Wildlife-Habitat Relationships in Oregon and Washington</i>. Corvallis, OR: Oregon St. Univ. Press.</p>
282	<p>Kerns, B.K., Alexander, S.J., Bailey, J.D. 2004. Huckleberry abundance, stand conditions, and use in western Oregon: evaluating the role of forest management. <i>Econ. Botany</i> 58(4):668-678.</p> <p>Analysis of data from old growth, young thinned, young unthinned Douglas-fir stands in western OR. All young stands 50 - 120 yrs old, with operational thinnings 10 - 25 yrs before this study. Old growth stands >200 yrs old.</p>

	<p><i>Vaccinium ovatum</i>, <i>V. parvifolium</i>, <i>V. membranaceum</i> studied. Results variable. Site history and conditions, such as substrate availability, apparently very important.</p> <p><i>Ovatum</i> associated with old growth and unthinned stands; stand thinning may not increase frequency or density. Slow-growing, shade tolerant sp. That lacks rhizomatous growth and might not be able to spread following stand thinning.</p> <p><i>Parviolium</i> significantly more dense in young thinned stands than in young unthinned stands. Density also related to intensity of thinning.</p> <p><i>Membranaceum</i> associated with old growth stands, but berry production tends to decline in closed-canopy forests.</p>
239	<p>Klinka, K., H.Y.H. Chen, Q. Wang and L. de Montigny. 1996. Forest Canopies and Their Influence on Understory Vegetation in Early-Seral Stands on West Vancouver Island. <i>Northwest Sci.</i> 70: 193-200. 1 - Very Relevant to Jackson WHMP Cover of salmonberry is strongly related to canopy cover, but not canopy species.</p> <p>While canopy cover has a strong influence on the understory vegetation, other factors including site quality, pre-disturbance vegetation, and type of disturbance have a greater influence on the understory composition.</p> <p>Both salmonberry and salal increased in the understory as the canopy cover decreased, and both were shaded out when canopy cover was 85%+</p> <p>***For lands where wildlife habitat improvement and wood production are the goals, forests on moist/very moist, rich/very rich soils should be opened to provide more light to understory when canopy closure reaches 80%.</p> <p>***Reducing canopy closure to 60% would result in 40% salmonberry cover. Canopy should be non-uniformly opened.</p>
254	<p>Knowe, S.A., Stein, W.I., Shainsky, L.J. 1997. Predicting growth response of shrubs to clear-cutting and site preparation in coastal Oregon forests. <i>Can. J. For. Res.</i> 27:217-226. 2 - Somewhat Relevant to Jackson WHMP</p>
151	<p>Manning, J.A., Edge, W.D. 2004. Small mammal survival and downed wood at multiple scales in managed forests. <i>J. Mammal.</i> 85(1):87-96. 3 - Not Relevant to Jackson WHMP The authors sampled small mammals, understory vegetation and CWD at multiple scales (trap sites, 1-hectare patches and stands in 2 Douglas-fir forests in western Oregon. Study objectives: Do CWD or understory vegetation vary among or within forest patches or among forest stands? Does variation in small mammals survival coincide with the scale in which CWD or understory vary?</p> <p>Understory vegetation explain most of the variation within patches, but did not vary among patches or stands. Survival of deer mouse (<i>Peromyscus maniculatus</i>) and creeping vole (<i>Microtus oregoni</i>) varied within patches by differing among individual home ranges, and was most related to CWD volume and herb and grass cover. Survival of deer mice was explained by a polynomial function of CWD within individual home ranges, and peaked at 2.0 cu m per 0.01 ha. Survival of creeping voles was dependent on a negative log function of CWD within home ranges, and was highest in home ranges lacking CWD.</p> <p>Results indicate these species may not be generalists, but rather specialists tied to specific amounts of particular habitat components within home ranges.</p>

78	<p>Marcot, B.G., Aubry, K.B. 2003. The functional diversity of mammals in coniferous forests of western North America. In: Zabel, C.J., Anthony, R.G., eds. Mammal community dynamics: management and conservation in the coniferous forests of western North America. New York: Cambridge Univ. Press:631-664.</p> <p>Proposes that the collective importance of terrestrial mammals to ecosystem structure and function is substantial and that the decline or loss of forest mammal species could have detrimental effects on ecosystem diversity, productivity, or sustainability.</p>
174	<p>McDonald, P.M. and P.E. Reynolds. 1999. Plant Community Development After 28 Years in Small Group-Selection Openings. Research Paper PSW-RP-241. Albany, CA: PSW Res. Stn. USDA Forest Service; 17p.</p> <p>In 1963, small openings (9, 18 & 27 m diameter, measured from drip-line to drip-line) were created by timber harvest, with ground scarification to reveal bare mineral soil and virtually no competing vegetation.</p> <p>In larger openings and on south aspects, plants developed better and more plants were able to establish.</p> <p>Between the 11th and the 28 year post-initiation:</p> <ul style="list-style-type: none"> >> number of species of conifer and hardwood seedlings remained constant, >>shrub species doubled, >>forbs increased by 50%, >>grass species increased then leveled off at 11th year levels. <p>28 years post clearing, shrubs in the small openings were those that tolerate shade.</p> <p>The 2 larger opening sizes had significantly higher shrub density than the small openings.</p> <p>Forb and grass densities were not statistically different among opening sizes.</p> <p>Fern density was significantly different between the 9 and 27 meter openings.</p> <p>Southern aspect created greater density of shrubs, forbs, grasses and ferns.</p> <p>Shade tolerant conifers were able to establish 25 years post gap creation.</p> <p>The 9m diameter openings were too small for development of most vegetation. Roots of adjacent trees likely extend throughout the gap and remove resources. However, shade tolerant species found this gap size quite suitable.</p> <p>Using group selection cuttings, stands can be regenerated with a diversity of species while maintaining high forest cover, and help to form a spatially distinct age class.</p>
301	<p>McKenzie, D, Halpern, C.B, Nelson, C.R. 2000. Overstory influences on herb and shrub communities in mature forests of western Washington, U.S.A. Can. J. For. Res. 30:1655-1666.</p> <p>3 - Not Relevant to Jackson WHMP</p> <p>Data comprise a subset of baseline forest veg measurements collected as part of DEMO study. 4 study locations: 3 in Cascade Range in Gifford Pinchot NF and one in Capitol State Forest. Forest zones represent western hemlock, grand fir and silver fir zones, but Douglas-fir dominates the canopy at all locations. Despite variability in stand age and canopy, many of the same taxa dominate the understory (vine maple, Oregon grape, and huckleberry spp.)</p> <p>Used correlation analysis, multiple regression and nonparametric models to evaluate relationships between canopy characteristics and herb and shrub layers.</p> <p>Overstory variables explained >50% of variation in total shrub cover and ca. 50% of the</p>

	<p>variation in vine maple, the most common species. Stronger relationships found between each of 3 functional groups of herb spp ("release" herbs capable of rapid expansion, late-seral herbs, and dominant herbs)*</p> <p>Results represent both direct resource limitations and time-dependent responses for which overstory characteristics may be surrogates. Release herbs positively correlated with variables that peak during early to mid-succession. Dominant herb species response weakly correlated with overstory variables: these spp are able to thrive and dominate the herb layer in a variety of forest conditions. Late-seral herbs, total shrubs and vine maple linked both to changes in available resources and to the passage of time.</p> <p>The models predicted best shrub cover and late-seral herb cover. Should be applicable to low and mid-elevation forest in western hemlock and Pacific silver fir zones.</p> <p>-----</p> <p>Dominant herbs: <i>Berberis nervosa</i>, <i>Gaultheria shallon</i>, <i>Polystichum munitum</i>, <i>Xerophyllum texan</i></p> <p>Release herbs: <i>Galium triflorum</i>, <i>Hieracium albiflorum</i>, <i>Linnaea borealis</i>, <i>Pteridium aquilinum</i>, <i>Rubus ursinus</i>, <i>Trientalis latifolia</i></p> <p>Late-seral herbs: <i>Achlys triphylla</i>, <i>Adenocaulon bicolor</i>, <i>Chimaphila menziesii</i>, <i>C. umbellata</i>, <i>Clintonia uniflor</i>, <i>Cornus canadensis</i>, <i>Disporum hookeri</i>, <i>Goodyera oblongifolia</i>, <i>Pyrola</i> spp, <i>Smilacina racemosa</i>, <i>S. stellata</i>, <i>Tiarella trifoliata</i>, <i>Trillium ovatum</i>, <i>Vancouveria hexandra</i></p>
170	<p>Messere, M. and P.K. Ducey. 1998. Forest Floor Distribution of Northern Redback Salamanders, <i>Plethodon cinereus</i>, in Relation to Canopy Gaps: first year following selective logging. <i>For. Ecol and Manage.</i> 107:319-324.</p> <p>Study of amphibians within gaps in northern hardwood forests, focusing on Northern Redback Salamanders.</p>
17	<p>Muir, P.S., Mattingly, R.L., Tappeiner, J.C., Bailey, J.D., Elliott, W.E., Hagar, J.C., Miller, J.C., Peterson, E.B., Starkey, E.E. 2002. Managing for biodiversity in young Douglas-fir forests of western Oregon. <i>US Geol. Surv., Biol. Res. Div., Biol. Sci. Report USGS/BRD/BSR -2002-0006.</i> 76 pp.</p> <p>2 - Somewhat Relevant to Jackson WHMP</p>
226	<p>Nelson, C.R., Halpern, C.B. 2005. Edge-related responses of understory plants to aggregated retention harvest in the Pacific northwest. <i>Ecol. Appl.</i> 15(1):196-209.</p> <p>2 - Somewhat Relevant to Jackson WHMP</p> <p>Part of DEMO study. Field study of short-term (1- and 2-yr) responses of understory plants to disturbance and creation of edges. See #214 for experimental design.</p> <p>2 yrs post-treatment, aggregates had gained an avg. of 2 forest spp (vs a loss of two in adjacent harvested areas) and less than 1 early-seral species (vs a gain of 9 in adjacent harvest areas). Aggregates supported populations of late-seral spp than disappeared from or declined in harvested areas.</p> <p>Aggregates showed edge-related changes in plant abundance: 1/3 of common understory herbs declined in cover toward the edge, changes in community comp were distinctly higher within 5 m of the edge vs. the center of the aggregate. Early-seral spp didn't establish in aggregates; only within 10 m of the edge. Herbaceous spp showed larger declines in abundance with proximity to edge than did shrubs; declines more prominent over time.</p> <p>Over short time frames, aggregates of at least 1 ha in size may host late-seral plant spp.</p>
203	<p>North, M., Chen, J., Smith, G., Krakowiak, L., Franklin, J. 1996. Initial response of understory plant diversity and overstory tree diameter growth to a green tree retention harvest. <i>Northwest Sci.</i> 70(1):24-35.</p>

	<p>2 - Somewhat Relevant to Jackson WHMP</p> <p>Field study examined response of understory plant diversity and basal area growth of retention trees 16 months and six years, respectively, after a green tree retention harvest (retaining 27 tph) in Seattle City Watershed. Both units replanted with tree seedlings at 740 tph.</p> <p>3 adjacent treatment areas: a clearcut, a dispersed green tree retention, and intact 65 yo forest.</p> <p>After 60 months, herb and shrub spp richness and evenness were significantly higher in the GTR cut than in the other 2 understory treatments. Although overall spp composition of the GTR was closer to the clearcut than the forest, the GTR retained more spp and cover of shade-tolerant plants important for maintaining understory diversity as canopy closure reduces understory light.</p> <p>Avg. response for GTR stands in HJ Andrews Experimental Forest, (Eugene, OR) thinned to 20, 43, and 45 tph 6 yrs harvest was a 15% reduction in increment growth compared to the control stands.</p>
111	<p>Pers. Comm: Alaback, P. 2007. E-mail on behalf of University of Montana. March 22, 2007.</p> <p>1 - Very Relevant to Jackson WHMP</p> <p>03/22/07 Huckleberry revert to a juvenile-like form with low growing, prostrate limbs and small evergreen leaves following canopy closure, and can persist as long as they are in deep shade. Following a disturbance, they will change growth form to an upright deciduous shrub. Red huckleberry keeps some of these evergreen shoots at the base and is most prone to this condition, but he has noted it in most NW huckleberry species.</p> <p>05/01/07 Elliptical shaped gaps may appear more natural and also be less prone to windthrow. Regeneration of hemlock can be reduced by opening the canopy enough to encourage shrub growth but not enough to encourage mass influx of hemlock seedlings. Suggests using a fisheye lens on digital camera to calculate the sun movement.</p> <p>5/25/07 Amount of light into forest under a gap varies depending on latitude and cloudiness. Hemlock invasion occurred on sites with greater than 4 or 5% light input. Old-growth is typically 0-5%. He suggests trying a couple different sizes of gaps aiming for 5, 10 and 15% light input to study the differences.</p>
14	<p>Public Utility District No. 1 of Snohomish County and City of Everett, Washington. 1988. Wildlife Habitat Management Plan, Henry M. Jackson Hydroelectric Project, 3 Vol., Paging various.</p> <p>1 - Very Relevant to Jackson WHMP</p>
263	<p>Reutebuch, S.E., Haring, C.A., DeBell, D.S., Marshall, D.D., Curtis, R.O. 2002. Silvicultural Options for Multipurpose management of west-side Pacific Northwest forests. In: Parker, S., Hummel, S.S., compilers. Beyond 2001: A silvicultural odyssey to sustaining terrestrial and aquatic ecosystems. Pro. 2001 Natl. Silvicultural Workshop, May 6-10, Hood River, OR. Gen. Tech. Rep. PNW-GTR-546. Pac. NW Res. Stn., Portland, OR. USDA Forest Service, pp. 38-46.</p> <p>2 - Somewhat Relevant to Jackson WHMP</p> <p>Describes long-term research study setup by Westside Silvicultural Options Team of the PNW research station (USFS). Authors point out that there are many new silvicultural approaches, but little research or operational experience that validate successful outcomes of new approaches to produce wildlife habitat, diversity, heterogeneity of stand structures, old growth features, etc. while still producing wood products. No young stands have been managed for an extended period under the proposed alternative methods. Most of the existing work with alternatives to even-age management in the douglas-fir region was done in old growth stands and has little relevance to management of young-growth stands.</p> <p>3 large-scale studies will focus on major stages of managed stands:</p>

	<p>**early development (precommercial thinning) **midrotation (commercial thinning) **regeneration harvest</p> <p>Objectives related to managing for wood production, wildlife habitat and other forest resource values.</p> <p>All 3 studies will measure response of overstory trees and understory plant species, and also CWD</p> <hr/> <p>Young Stands: Experiments set up in Mt. St. Helens Nat'l Volcanic Monument, young, vigorous uniform Douglas-fir plantations, planted in mid-1980s. Treated in 1994-95. Remeasured 3 and 5 yrs later.</p> <p>Study goals: 1. Test how silviculturally induced variation in tree spp composition and stand structure affect plant and animal populations. 2. Quantify the effects of different silvicultural regimes on tree and stand characteristics and production of forest products.</p> <p>5 treatments for young stands: 1. Control plots. Primarily Douglas-fir 680 tpa, one canopy layer, little understory veg. 2. Thinning to 50% of density with uniform tree spacing, and no alteration of spp composition. Possible future commercial thinning, retaining largest, most vigorous Douglas-fir in uniform spacing. 3. Uniform thinning as in 2., with evening spaced openings (40 x 40 ft). Supplemental plantings of red alder, western hemlock and western redcedar. Future commercial thinning to emphasize increasing tree species diversity rather than uniformity. 4. Variable density thinning with variable-size openings to increase structural heterogeneity. Stands evenly thinned as in 2., then openings of 30 x 30 ft, 40 x 40 ft., and 50 x 50 ft. created. No underplanting. Future commercial thinning emphasizing increasing heterogeneity and tree species diversity--only allow harvest of Doug-lar and expand or creating new openings. 5. Treatment as in 4., but interplant openings with red alder, western hemlock and western redcedar. 30 large tps fertilized--for future snag production. Future commercial thinning to accelerate development of multi-layered, uneven-aged mixed-species stands.</p> <hr/> <p>Midrotation stands: Westside Silvicultural Options and the Ecological Foundations of Biodiversity Teams from the Olympic Forestry Sciences Lab designed the Olympic Habitat Development Study of silvicultural options for closed-canopy midrotation stands on the Olympic Peninsula. Study stands are 30- to 70-yo stands of Douglas-fir, western hemlock and Sitka spruce. Pretreatment baseline data on small mammal and amphibian populations, understory species, and CWD quantity collected from 1995 - 1998. Treatment of some blocks in 1997 - 99. Remaining blocks delayed. Some post-treatment surveys completed.</p> <p>Study Goals: 1. Test efficacy of specific mgt. practices to accelerate late-successional stand structure and plant and animal communities. 2. Test if accelerating the development of late-successional structures in closed-canopy midrotation stands will increase habitat value for terrestrial amphibians and small mammals. 3. Develop and test operational prescriptions that allow wood production consistent with sustainable ecosystems.</p> <p>Variable-density thinning: 10 % of the area in no-cut patches to protect existing snags and</p>
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	<p>forest floor patches, 15% in small (65 ft x 65 ft) gaps, 75% lightly thinned from below (removal of 30% of basal area). CWD treatments.</p> <p>5 treatments for midrotation stands:</p> <ol style="list-style-type: none"> 1. Untreated control 2. VDT with scattered slash and logs. Additional trees felled to supplement CWD levels. 3. VDT with scattered slash and clumped logs. Additional trees felled to supplement CWD levels. 4. VDT with slash piles and clumped logs, and supplemental planting of trees in gaps. Additional trees felled for CWD. 5. VDT with scattered slash and no supplement CWD. <hr/> <p>Regeneration harvest methods: Silvicultural options for harvesting young-growth forests, in collaboration with DNR on Capitol Forest. First block harvest in 1998, replanted in 1999. Post-treatment song bird survey.</p> <p>Study goals:</p> <ol style="list-style-type: none"> 1. Evaluate biological, economic and visual effects of alternative timber harvest and management regimes for young-growth forests. 2. Provide demonstrations of contrasting silvicultural systems that are biologically feasible for managing young-growth forests. <p>Treatments for young-growth stands;</p> <ol style="list-style-type: none"> 1. Clearcut and manage similar to traditional even-aged standards, with PCT and CT as rel. stand densities exceed desired targets. 2. Retained overstory - Resembles shelterwood, but residual trees carried through next rotation. 15 evenly spaced tpa retained. 3. Small patch cutting - An even-aged system with small openings (1.5 to 5 ac.) created over 20% of the unit. May concurrently thin remainder of stand. Future thinning if densities exceed targets. 4. Group selection - An uneven-aged system with evenly-spaced openings (up to 1.5 ac.) created over 20% of the unit. May concurrently thin remainder of stand. Future thinning if densities exceed targets 5. Extended rotation with commercial thinning. Thin from below, removing 30% of basal area throughout stand. Future thinning if densities exceed targets. 6. Unthinned control <p>Regeneration in treatments 1-4 will be by planting in openings >0.1 ac. No planting in 5-6.</p>
23	Scherer, G.m Zabowski, D., Java, B, Everett, R. 2000. Timber harvesting residue treatment. Part II. Understory vegetation response. Forest Ecology and Management 126:35-50.
255	<p>Stein, W.I. 1997. Ten-year survival and growth of planted Douglas-fir and western redcedar after seven site-preparation treatments. W. J. Appl. For. 12(3):74-80.</p> <p>2 - Somewhat Relevant to Jackson WHMP</p> <p>Some of the site-preparation techniques not relevant to allowable practices on WHMP lands. Western red cedar and Douglas-fir were planted together after applying 7 site-preparation methods at one site in the Oregon Coast Ranges:</p> <p>(1) no site prep, (2) spot-clear in a 1.2 m radius around each tree seedling, (3) spray with glyphosate, (4) broadcast burn, (5) slash and burn, (6) spray and burn, (7) burn and sow grass seed.</p> <p>Survival of red cedar markedly less than Douglas-fir due to browsing. Site prep by broadcast burning generally yielded the best results, but sowing grass after broadcast burning produced</p>

	Douglas-fir responses similar to those for no site prep. Where grass was sown, herbaceous cover was more abundant and tall, and development of red alder was delayed.
212	Thysell, D.R., Carey, A.B. 2001. Manipulation of density of <i>Pseudotsuga menziesii</i> canopies: preliminary effects on understory vegetation. <i>Can. J. For. Res</i> 31(9):1513-1525. 1 - Very Relevant to Jackson WHMP
28	US Forest Service. 2002. Canopy gaps and dead tree dynamics: poking holes in the forest. <i>Science Findings</i> . PNW 43. 1 - Very Relevant to Jackson WHMP Within gaps, temperatures (air & soil) are higher, increased moisture leads to increased decomposition and therefore greater nutrient availability, thus increasing the productivity of the surrounding forest. Plant species diversity is higher in gaps than the surrounding forest. Douglas-fir growth was low except in the largest gaps, hemlock growth increased dramatically with gap size, and silver fir responded least to gap size. Overstory tree growth increased around the gaps, suggesting that a below-ground "gap" is also created. Southern areas within gaps had abundant growth of a wide range of species. Douglas fir was more successful in gaps of 0.33 ac or larger, faring especially well in the northern portions with more sunlight. Hemlock and silver fir were more opportunistic, and had higher growth rates in smaller gaps and shady areas of larger gaps. Gaps with diameters of about 80' (0.10 ac) had the highest available moisture. Larger gaps saw an increase in moisture and higher temperature, leading to expedited decomposition and greater nutrient availability. "Many national forest managers are incorporating gaps as part of thinning prescriptions designed to diversify dense plantings and accelerate development of late-successional conditions"
47	US Forest Service. 2002. Restoring complexity: second-growth forests and habitat diversity. <i>Science Update</i> 1. May 2002.
71	Van Pelt, R. 1995. Understory Tree Response to Canopy Gaps in Old-Growth Douglas-fir Forests of the Pacific Northwest. Seattle, WA. Univ. of WA. PhD Dissertation; 237p. 1 - Very Relevant to Jackson WHMP Master's thesis available from UW library. Variability in the canopy was highly correlated with understory light levels and shrub cover values. Spatial patterns of regeneration trees were poorly correlated with canopy height, canopy density and location of gaps Light environment is highest 18-20m north of the gap center. Understory trees that responded to gap formation did so within 5 years, but many did not show a response. Shrub and herb cover showed stronger correlation with canopy gaps and were more adaptable to changes in the canopy environment.

	<p>Noted that Spies et al 1990 reported that median gap size in OG DF forests was 85m² (765ft²), small enough that only shade tolerant species can take advantage.</p> <p>Hemlock crowns are more densely packed with needles than Douglas-fir.</p> <p>High latitude of Pacific forests and the height of the canopy allow light to filter in at relatively high angles.</p> <p>Understory tree location was poorly correlated with gap location, but shrub location was better correlated with gap location.</p> <p>Several natural gaps were analyzed to determine the gap initiation year and cause, if possible. One gap nearly doubled in size over a 40 year period, with at least 3 separate events causing overstory tree mortality.</p> <p>Trees may take several years to reveal effect of release from competition when a neighbor dies.</p> <p>Highest branch growth of residual trees around experimental gaps (0.35ha) was by the third growing season and was south of center, where diffuse light levels were high, but direct light levels were low.</p> <p>Trees in direct light suffered higher rates of mortality and retained needles for a shorter duration.</p> <p>The northern part of the gap exhibited the greatest change in biological factors measured; this area had the highest soil light and soil temperature levels, and consequently the highest mortality and needle loss on surviving trees.</p>
110	<p>Van Pelt, R. And J. F. Franklin. Response of Understory Trees to Experimental Gaps in Old-Growth Douglas-Fir Forests. <i>Ecol. Appl.</i> 9: 504-512. 1 - Very Relevant to Jackson WHMP Artificial gaps, 0.2 ha in size were created.</p> <p>Understory trees may require several years to acclimatize to overstory removal (3 years seemed common in this study).</p> <p>Light levels in the northern portions of the gaps increased by up to 500%, and soil temps at the surface increased by as much as 25 degrees C. This caused severe stress to many understory trees. Within 3 years, understory trees within the gaps had developed sun needles and were responding positively to the increased light.</p> <p>Understory trees experienced up to 1 month of additional growing season due to the removal of overstory trees.</p> <p>Areas of gaps that receive high diffuse light showed the highest growth rates, since they were not stressed by a great increase in direct light. The highest mortality was in areas that received an increase in direct light.</p> <p>Since a great deal of light reaching the forest floor in the northern hemisphere is from oblique angles, tree response to canopy gaps may be greatest outside of the gap.</p>
109	<p>Wender, B.W., C. A. Harrington and J.C. Tappeiner II. Flower and Fruit Production of Understory Shrubs in Western WA & OR. <i>NW Sci.</i> 78:124-140. 1 - Very Relevant to Jackson WHMP</p>

	<p>This study only considered a gap to be such when the ratio of gap width to canopy height was 1.0 or greater.</p> <p>Flowering was not observed on vine maple <10 years old (y/o), but was seen on stems up to 64 y/o.</p> <p>Hazelnut and huckleberry also flowered at ages > 20 y/o.</p> <p>Heavily flowering shrubs were more common in gaps than under intact canopies.</p> <p>Flower production of evergreen huckleberry (<i>V. ovatum</i>) increased as the overstory of conifers increased, but decreased as the crowns of overstory trees overlapped.</p> <p>Intensity of commercial thinning was strongly correlated to production outcome for Oregon grape, ocean spray, red huckleberry, and was strongest for salal.</p> <p>Moderate thinnings, followed by heavy, then light thinning treatment were found to have the greatest impact on the probability of shrub flowering.</p> <p>Red huckleberry did not respond differently to varying levels of thinning.</p> <p>Plant size and age is more important in determining the likelihood of flowering for common understory shrubs than overstory density.</p> <p>The resources available also impact flower/fruit production by influencing the size of the plant, thus, canopy gaps should increase the amount of resources available to the plants and should in turn lead to increased flower/fruit production.</p> <p>Woody perennials have the ability to store resources for long periods of time, and therefore gap-induced plant growth may be hard to predict.</p> <p>Responses to gap creation or thinning may be delayed if conditions during the growing season are unfavorable (i.e. precipitation).</p> <p>Older legacy shrubs, or pockets thereof, may needed to be protected within a stand to ensure that large individuals are maintained into the next forest generation.</p>
22	<p>Western Forestry and Conservation Association. 2006. Managing for Wildlife Habitat in Westside Production Forests. Proceeding of a Workshop on October 18, 2006. Vancouver, WA.</p> <p>1 - Very Relevant to Jackson WHMP</p>
58	<p>WSU Coop. Extension. 1998. Managing deer on small woodlands. Woodland Fish and Wildlife. WSU Cooper. Extension. MISC0189 Rev. July 1998.</p>

Snags and Gaps

106	<p>Alaback, P.B., and J. C. Tappeiner II. Response of Western Hemlock and Early Huckleberry (<i>Vaccinium Ovalifolium</i>) Seedlings to Forest Windthrow. <i>Can. J. For. Res.</i> 21:534-539.</p> <p>2 - Somewhat Relevant to Jackson WHMP</p> <p>Study site is Juneau, AK, but discussion of plant responses to gaps is relevant.</p> <p><i>Vaccinium ovalifolium</i> (abbreviated for this summary as VAOV - authors call this early huckleberry, Forest Service in R6 calls it Oval-leaf Huckleberry) is known to be highly shade tolerant and produces a large amount of viable seeds. New plants can emerge from underground rhizomes. Initially, new plants send most of their photosynthates to the rhizomes and root starch reserves. So above ground growth may be limited for several years.</p> <p>VAOV seedlings known to be over 2 years old were still in the juvenile prostrate evergreen growth form. This form only occurs during the first few years of growth in open areas, but under dense shade, it can persist for more than a decade. Leaves of this form are typically 1 cm or less in length and are evergreen, as opposed to the adult form, which has large leaves 5 cm or longer.</p> <p>After the windthrow event, seedlings of "buried-seed strategists" such as elderberry and salmonberry were much more frequent than in the adjacent second-growth forest.</p> <p>Three growing season following the windthrow event, the density of hemlock seedlings was little changed, but density of huckleberry had increased.</p> <p>The authors suspect that with thinning or natural disturbance in dense second-growth hemlock stands, hemlock will eventually produce a second canopy layer and will shade out the lower herb/shrub layers.</p> <p>One to two year old hemlock seedlings appeared to be released from low light levels after the windthrow event, becoming the primary source of regeneration, as opposed to new seedlings.</p> <p>Some form of forest floor disturbance such as fire or soils mixing may be required to prevent young hemlocks from overtaking the site. This would also create microsites for a wider range of plants to propagate.</p>
235	<p>Aubry, K.B., M.P. Amaranthus, J. D. White et al. 1999. Evaluating the Effects of Varying Levels and Patterns of Green-tree Retention: Experimental Design of the DEMO Study. <i>Northwest Sci.</i> 73: 12-26.</p> <p>1 - Very Relevant to Jackson WHMP</p> <p>Aggregated retention is thought to be more effective at maintaining a broad array of structural elements, such as multiple canopy layers and understory vegetation, and snags of various sizes and decay classes that would not be possible in dispersed retention systems.</p> <p>Intact patches of habitat also act as refugia for organisms that will recolonize the harvest unit.</p> <p>Study set-up:</p> <p>*Snags that were deemed safe to work around were retained.</p> <p>*6.5 additional dominant/co-dominant green trees/ha were retained for snag creation.</p>
42	<p>Aubry, K.B., Raley, C.M. 2002. Selection of nest and roost trees by pileated woodpeckers in coastal forests of Washington. <i>J. Wildl. Manage.</i> 66:392-406.</p> <p>1 - Very Relevant to Jackson WHMP</p> <p>PWP were tracked using radio telemetry, calling and ground searches over a 6 year period in coastal WA forests. A total of 25 nests and 144 roosts were found. Decadent live trees were used as often as snags for both nesting and roosting. Silver fir were preferred (selected for) for</p>

	<p>nesting and Cedar for roosting; Hemlock were selected against for both activities, but when they were used, 2/3 of the time they were decadent, but not dead. Nest snags typically were sound snags with intact bark and limbs still carrying small twigs/dead foliage.</p> <p>Nest trees average 101.2 cm dbh x 39.3 m tall. More than 3/4 of nest openings were within the canopy, and all nest openings in decadent trees were several meters above the highest live limb (an average of 4.6m above).</p> <p>Roost trees averaged 149 cm dbh x 36.5m tall. Most roost trees were Hemlock (52%) or Cedar (42%). Roost snags were most often (73%) in later stages of decay with broken tops (71%). When used for roosting, Cedar were usually live trees (77%). Roost openings averaged 23m above ground and in decadent trees were usually below the highest live limb.</p> <p>Preferences: Trees less than 17.5m tall were selected against for both nesting and roosting. Nest trees ranged from 65-154cm dbh but PWP were not selective among these sizes. Roost trees ranged from 65-309cm dbh but PWP preferred trees 155-309cm dbh, used trees 125-154 cm dbh in proportion to their availability and selected against trees 65 - 124cm dbh.</p> <p>Nesting and roosting plots had higher densities of decadent and large trees and greater tree species diversity than areas not chosen for nesting or roosting sites. The probability that a site would be chosen for nesting or roosting increased 300% for each additional decadent tree/0.4ha, 200% for each additional tree species/0.4ha, and 130% for each additional large snag/0.4ha.</p> <p>PWP foraging on logs was seldom seen, and when it was observed, it was usually on a log suspended off the ground.</p> <p>Recommendations for PWP in W Wa (from Nietro et al. 1985) are based solely on the requirements for nesting (6 hard snags \geq 63.5cm dbh/40.5 ha).</p> <p>In this study, PWP preferred decadent trees for both nesting and roosting, and used 7 roost trees each year, on average.</p> <p>Since living trees with heart-rot fungi will provide nesting and roosting habitat longer than a hard snag, managing for decadent trees in addition to snags would ensure that nesting and roosting habitat are available for a much longer period of time than managing solely for hard snags.</p>
43	<p>Aubry, K.B., Raley, C.M. 2002. The pileated woodpecker as a keystone habitat modifier in the Pacific Northwest. In W.F. Laudenslayer, Jr. (and others), tech. coords. Proceedings of the Symp. on the Ecology and Management of Dead Wood in Western Forests. PSW-GTA-181. Albany, CA: US Forest Service, Pacific SW Res. Stn. pp. 257-274.</p> <p>1 - Very Relevant to Jackson WHMP</p> <p>Mike - Snags:</p> <p>Recommendations for forest management in matrix lands covered by the NW Forest Plan:</p> <p>retain 15%+ of the harvested area as green tree reserves; 70% of which should be clumps 0.2 to 1.0 ha in size, the remainder dispersed either individually or small clumps < 0.2 ha in size. These clumps & dispersed groupings should be comprised of the largest, oldest, decadent or leaning trees and hard snags occurring within the unit. Snag management would primarily occur within these areas of green-tree retention.</p> <p>As a minimum, snags are to be retained within the harvest unit at levels sufficient to support species of cavity-nesting birds at 40 % of potential population levels.</p>

	Bernice, table 3 provides CWD recommendations.
19	<p>Aubry, Keith B. and Catherine M. Raley. Landscape-Level Responses of Pileated Woodpeckers to Forest Management and Fragmentation: A Pilot Study. Progress Report 1990 and 1991. USDA Forest Service PNW Research Station. January 8, 1992. 73p.</p> <p>1 - Very Relevant to Jackson WHMP</p> <p>Half of all PWP nest cavities were in snags with broken tops, and half in live trees with broken tops. 75% were in Hemlock, 25% in Cedar. Avg DBH of all nest trees was 97.0cm, and nest cavities averaged 37.6m high. 73% of all roost cavities were in Hemlock, 27% in Cedar. Mean number of ALL decadent trees greater than 5m tall was 22.33/ha, mean number of snags alone was 20.55/ha. Logs were relatively unimportant as a food source in this study area.</p>
115	<p>BC Ministry of Environment and BC Ministry of Forests. 1993. Guidelines for maintaining biodiversity during juvenile spacing. BC Environment. Canada-British Columbia Forest Resource Development Agreement FRDA II.VI.</p> <p>2 - Somewhat Relevant to Jackson WHMP</p> <p>General basic descriptions of habitat features associated with biodiversity, with a few useful concepts for restocking at the stand level:</p> <p>Retain 5-10 live wildlife trees/hectare, 3 of which should be within the upper 10% of the diameter range of the stand</p> <p>Retain wildlife trees in small groups, at the edge of surrounding forest to avoid safety and operational conflicts. Isolated trees more susceptible to windthrow, offer less cover for wildlife.</p> <p>All stumps greater than 25 cm diameter, less than 3 m in height should be retained for woodpecker foraging.</p> <p>Cut shrubs taller than 3 m to promote coppicing and improve browse.</p> <p>Leave pre-existing wildlife trails unobstructed through directional falling and/or slash removal.</p> <p>Wider or patchy spacing in areas adjacent to water to encourage growth of woody forage species. Patchy spacing with some areas of higher density, will provide cover.</p> <p>Wider spacing adjacent to deciduous patches to promote forage species.</p> <p>Examples of contract specs</p>
97	<p>Bonar, R.L. 2000. Availability of Pileated Woodpecker Cavities and Use by Other Species. J. Wildl. Manage. 64:52-59.</p> <p>3 - Not Relevant to Jackson WHMP</p> <p>Study conducted in Alberta Canada, in Lodgepole Pine-Engelmann Spruce forests.</p>
186	<p>Bradbury, R.B., R.A. Hill, D.C. Mason, J.D. Wilson et al. 2005. Modeling relationships between birds and vegetation.</p> <p>3 - Not Relevant to Jackson WHMP</p> <p>Study conducted on agricultural land in England.</p>
93	<p>Brandeis, T.J., M. Newton, G.M. Filip and E.C. Cole. 2002. Cavity-Nester Habitat Development in Artificially Made Douglas-fir Snags. J. Wildl. Manage. 66:625-633.</p> <p>1 - Very Relevant to Jackson WHMP</p> <p>This is part of an on-going study in forest land in W. OR among 50- to 55-year old Douglas-fir stands that have previously been thinned to a basal area of 18 to 31sq m/ha. Created snags were Douglas-fir and averaged 42.3cm dbh (range of 28.5-72.7 cm dbh) and average height</p>

	<p>prior to treatment of 37m. Methods used were girdling at the base, 2 different herbicide applications, topping at the base of the live crown (fully topped) and topping in the middle of the live crown (mid-topped). One year later, a subset of trees within each creation category was inoculated with either a heart-rot or sapwood-rot fungi.</p> <p>Of the two topping methods, approximately 95% of the fully topped and 35% of the mid-topped trees were dead after 4 years.</p> <p>Artificial inoculation did not appear to increase the number of external fruiting bodies on the created snags.</p> <p>The fully- topped trees had the highest levels of small foraging holes, cavities and bark patches removed.</p> <p>Woodpecker activity was not affected by the method of snag creation or inoculation, and intensified over time. The greatest single factor in determining snag suitability for foraging is the length of time the tree has been dead.</p>
236	<p>Brett, T.A. 1997. Habitat Associations of Woodpeckers in Managed Forests of the Southern Oregon Cascades. Corvallis, OR, USA. Oregon State Univ. Master's Thesis; 95p. 1 - Very Relevant to Jackson WHMP no PUD copy - available from OSU library.</p> <p>Previous research has shown that woodpeckers select for the tallest and largest snags available in all forest types.</p> <p>Higher nest cavities are believed to reduce predation.</p> <p>Recommend providing for the maintenance of 3 to 11 large (>50cm dbh) tall snags/acre depending on site conditions.</p> <p>Author predicts that Nietro 1985 recommendations are too low to sustain viable populations of cavity nesters and notes that another study shows that a majority of biologist believe that current guidelines for snag management are inadequate to maintain target populations of woodpeckers.</p> <p>For nest trees of all 7 species of cavity nesters present, average nest tree dbh = 79cm.</p> <p>Of 163 nest trees found over the 2 year study, 14% were decay class I, 45% class II, 30% class III, 10% class IV.</p> <p>Red-breasted Sapsucker: Nest trees had mean dbh of 80.5cm (random trees were 42.1 cm). Mean Nest ht = 20.4m mean Tree ht = 27.5m Predicted through logistic regression that for each 10cm increase in dbh, likelihood of use increases 10.5x.</p> <p>Hairy Woodpecker: Mean nest tree dbh = 80.4 cm (random = 42.1cm) Mean Nest ht = 18.6m mean Tree ht = 28.0m Predicted through logistic regression that for each 10cm increase in dbh, likelihood of use increases 10.4x. Decay class III snags were 16.4x more likely to be used for nesting than class IV.</p>

	<p>Northern Flicker: Mean nest tree dbh = 77.7 cm (random = 42.1cm) Mean Nest ht = 14.3m mean Tree ht = 19.7m Predicted through logistic regression that for each 10cm increase in dbh, likelihood of use increases 10.2x.</p> <p>Management emphasis should be placed on maintaining larger snags because they provide more foraging substrate, more available nest cavity potential and remain standing longer.</p> <p>Hairy WP were more associated with class III snags; Flickers and RB Sapsuckers were more associated with snags having broken tops.</p> <p>Habitat edges were chosen more often than random for nest site location. RB sapsuckers chose these areas for more than 33% of nest sites found; flickers (24%) and hairy WP (19%) also used these areas more than random (7%), but to a lesser degree than the sapsucker.</p> <p>Openings and open-canopy forests were found to have greater abundance of woodpecker nests, several past studies have also found that woodpeckers will nest in young regenerating forests if adequate numbers and sizes of snags are present.</p> <p>Landscape analysis revealed that woodpecker nest densities were higher in areas with greater habitat complexity (specifically patch heterogeneity and edge habitat).</p> <p>** Recommends snags greater than 80cm be retained in harvest units. This is the average diameter of nest tree used by the 3 species studied.</p> <p>Providing snags larger than the average is preferable as they provide more suitable habitat over the long run.</p> <p>** Recommends using alternatives techniques over a broad landscape, such as partial and shelterwood cuts. Small 20 to 30 acre patches created over a landscape would create habitat diversity but still maintain the integrity of the forest matrix.</p> <p>Small pockets of armillaria root rot could be preserved (they spread at about 1m/yr) to provide a continuous supply of nesting habitat.</p>
329	<p>Brown, E. R., tech. ed. 1985. Management of Wildlife and fish habitats in forests of western Oregon and Washington. U.S. Forest Service ubl. No. \$6-F&WL - 192-1985. Portland, OR.</p> <p>1 - Very Relevant to Jackson WHMP</p> <p>Chapters in this document provide the basis for WHMP management techniques dealing with timber harvest, silviculture, deer forage, snag and coarse woody debris management.</p>
290	<p>Bull, E.L., J.J. Akenson, B.J. Betts and T.R. Torgersen 1995. The Interdependence of Wildlife and Old-Growth Forests In: Bradford, P., T. Manning and B. I'Anson eds. Wildlife Tree/ Stand-Level Biodiversity Workshop Proceedings. Victoria, B.C. October 1995. 71-76.</p> <p>1 - Very Relevant to Jackson WHMP</p> <p>Mistletoe brooms are important nest structures for Great Gray and Great Horned Owls, as well as American Marten.</p> <p>Pileateds excavate new nests each year, and typically roost in hollow trees.</p> <p>The density of large green trees, canopy height, number of canopy layers and density of hard snags were all positively associated with woodpecker abundance.</p> <p>Vaux's swifts are known to be dependent on large diameter, hollow trees for nesting and</p>

	<p>roosting.</p> <p>Black bears commonly use hollow trees for denning. These trees averaged 114cm dbh (range 91-160cm) and 19m tall (range 8-30m). Trees with top entries are most commonly used by young bears and females, because they are more secure from predators.</p> <p>Martens regularly use large-diameter snags, logs and live trees as rest sites. 36% of rest sites were in platforms, usually resulting from mistletoe.</p> <p>Cavities made up 23% of rest sites, and hollow logs accounted for 10%.</p> <p>Bat roosts were usually found in snags (67% of roosts). The average dbh was 68 cm and height was 22m. The actual roost site was typically high in the tree, averaging 12m.</p>
206	<p>Bunnell, F.L., Houde, I., Johnson, B., Wind, E. 2002. How dead trees sustain live organisms in western forests. Gen. Tech. Rep. PSW-GTR-181. USDA Forest Service. Pp.291-318.</p> <p>2 - Somewhat Relevant to Jackson WHMP</p> <p>Ensure sustained provision of dying and dead wood. Retain trees and snags of both hardwoods and favored conifer species, retain a range of size and age classes of dead wood, ensure that large trees or snags are retained, don't do the same thing everywhere. Retention of trees in patches reduces safety risks of snag retention and windthrow, and facilitates retention of a range of size and decay classes. It also concentrates recruitment of down wood. Any single approach will disadvantage some group of species, so a range of practices is preferable if a range of species is to be sustained in an area.</p>
210	<p>Bunnell, F.L., Houde, I., Johnson, B., Wind, E. 2002. How should we spatially distribute dying and dead wood? Gen. Tech. Rep. PSW-GTR-181. USDA Forest Service. Pp. 739-752.</p> <p>2 - Somewhat Relevant to Jackson WHMP</p> <p>Review article describing mammal use of CWD and pros and cons of its distribution of harvested units. Aggregations are used by several small mammals, both predator and prey. More evenly dispersed retention favors some fungi and bryophytes. "Because there is no unequivocal best way to distribute logging residuals, the wisest approach is not to do the same thing everywhere." Distribution can be manipulated by retaining live trees to fall after harvest.</p> <p>Recommendations:</p> <p>Logs as small as 6 cm are used by shrews, but in some forest types, larger mammals prefer significant amount (100 – 200 cu m/ha or more) and sizes (>50 cm diameter) of downed wood. Mammals such as marten, fisher and black bear require scattered, large pieces, 50 to 100 cm diameter.</p>
231	<p>Canham, C.D., J.S. Denslow, W.J. Platt, J.R. Runkle, T.A. Spies and P. S. White. 1990. Light Regimes Beneath Closed Canopies and Tree-Fall Gaps in temperate and Tropical Forests. Can. J. For. Res. 20:620-631.</p> <p>2 - Somewhat Relevant to Jackson WHMP</p> <p>Light penetration into the forest and its associated effects can extend considerable distances beyond the edges of canopy gaps.</p> <p>PAR = photosynthetically active radiation</p> <p>During the course of the growing season, both total open-site PAR and total closed-canopy PAR are roughly evenly split between diffuse and direct radiation.</p>
54	<p>Carey, A.B. 2002. Response of northern flying squirrels to supplementary dens. Wildl. Soc. Bull. 30(2):547-556.</p>
125	<p>Carey, A.B., Holt, M.M., Horton, S.P., Biswell, B.L. 1991. In: Ruggiero, L. F. et al, editors. Wildlife and</p>

	<p>Vegetation of Unmanaged Douglas-fir Forests. USDA Forest Service, GTR-PNW-285. pp 123-144.</p> <p>1 - Very Relevant to Jackson WHMP</p> <p>For 9 species of cavity-using birds, 277 nests were located. All species preferred Douglas-fir snags >50cm dbh for nesting. DBH range was 54cm for N pygmy owl to 113cm for red-breasted sapsucker, with the mean being 94cm.</p> <p>Abundance and diversity of cavity-using birds was directly correlated with large snags.</p> <p>"Large, and especially very large, moderately decayed snags are of major importance to cavity-using birds."</p> <p>Large snags were selected in greater proportions than their availability, even though small snags (<50 cm) were abundant.</p>
95	<p>Chambers, C.L., T. Carrigan, T.E. Sabin, J. Tappeiner, and W.C. McComb. 1997. Use of Artificially Created Douglas-fir Snags by Cavity-Nesting Birds. W. J. Appl. For. 12:93-97.</p> <p>1 - Very Relevant to Jackson WHMP</p> <p>Snags were created by topping either scattered or clumped live Douglas-fir trees with chainsaws. These averaged 3.8/ha, 17m tall and 75cm dbh. Three stand types were manipulated: modified clearcuts, two-story stands and small-patch group-selection stands.</p> <p>After treatment, cavities were found more often in the two-story and modified clearcuts than the small-patch stands. Snag pattern (clumped vs. scattered) did not affect bird use. Snags were used within 5 years of creation, and secondary cavity nesters were also found, indicating that nest sites were available within a short time period following topping.</p> <p>Hardwoods also provide important nesting opportunities. Big leaf maple (33.0 to 41.7cm dbh, 14.3m ht) was the most common to hold cavities.</p> <p>Clumping of snags may reduce bird densities if clumps are not adequately spaced, due to territoriality.</p>
161	<p>Conner, R. N., S.D. Jones & G. D. Jones. 1994. Snag condition and woodpecker foraging ecology in a bottomland hardwood forest. Wilson Bul. 106: 242-257.</p> <p>3 - Not Relevant to Jackson WHMP</p> <p>Study area is in Texas.</p>
271	<p>Daniels, L.D., Dobry, J., Klinka, K., Feller, M.C. 1997. Determining year of death of logs and snags of Thuja plicata in southwestern coastal British Columbia. Can. J. For. Res. 27:1132-1141.</p>
187	<p>Ducey M.J., G.J. Jordan, J.H. Gove, and H.T. Valentine. 2002. A practical modification of horizontal line sampling for snag and cavity tree inventory. Can. J. For. Res. 32: 1217-1224.</p> <p>3 - Not Relevant to Jackson WHMP</p> <p>Primarily discusses a modified version of line sampling using a prism.</p>
40	<p>Duncan, S. Coming home to roost: The pileated woodpecker as ecosystem engineer. Science Findings 57. October 2003.</p> <p>1 - Very Relevant to Jackson WHMP</p> <p>Summary article based on interviews with Keith Aubry and Catherine Raley from the PNW Research Station, USDA Forest Service, Olympia, WA.</p> <p>Within the range of the N. spotted owl, pileated woodpeckers were found to nest in live, decadent trees equally as often as they do in snags and to use different tree species with different decay characteristics for roosting versus nesting.</p> <p>Nest cavities have single large entrances (usually 21cm wide x 51cm deep). New nest</p>

	<p>cavities are excavated each year with diameter, height, decay characteristics and surrounding habitat conditions being important factors.</p> <p>Converse to other woodpecker species in the PNW, Pileateds select nest trees that are in the early stages of heartwood decay and that have relatively sound wood.</p> <p>Pileateds show a strong preference for decadent trees for nesting, based on the high proportion of use versus their extremely low density in most forests. Decadent trees are considered to be MORE IMPORTANT for nesting by Pileateds than snags.</p> <p>Nest trees differed in both size and decay characteristics from roost trees. Nest trees typically had only early stages of heartwood rot. Roost trees were typically in trees that had advanced heart rot that had created large natural hollows and had both natural and excavated openings.</p> <p>Silver fir was preferred as a nest tree, but cedar was preferred as a roost tree and not used for nesting.</p> <p>A pair of Pileateds uses only 1 nest tree each year, but each bird used an average 7 or more different roost trees in a year.</p> <p>Decadent trees may be easier to leave within harvest units because they pose significantly less safety risk and will also provide habitat for Pileateds longer than a snag will.</p> <p>Mgmt Recommendation: Standing dead wood in west side forests should be given more consideration because Pileateds were rarely noted to forage on logs, since they likely become too wet to support carpenter ant colonies unless suspended above the forest floor.</p> <p>Nest trees differ from roost trees in both size and decay characteristics. Nest cavities are typically in trees where the heartwood is only partially softened and is still in the early stages of decay. But roost cavities are typically large natural hollows caused by the late stages of heartwood decay and may have both natural and excavated openings.</p> <p>Pacific silver fir was a preferred nesting species, but cedar was preferred for roosting and not used for nesting.</p>
69	<p>Duncan, S. 2002. Dead wood all around us: think regionally to manage locally. USDA Forest Service PNW Res. Stn. Science Findings 42. March 2002. 6p.</p> <p>1 - Very Relevant to Jackson WHMP</p> <p>Summary of interview with J. Ohmann and K. Waddell regarding the compilation of a dead wood database. This is "the most comprehensive study yet available of dead wood across both managed and unharvested forests of all ownerships in the PNW." The compilation included data from more than 16,000 field plots across 9 habitat types.</p> <p>Key points include:</p> <p>Large snags were more than 2x as dense in unharvested forests than harvested areas.</p> <p>Average densities of snags at least 10" dbh ranged from 3 to 91 tpa.</p>
233	<p>Everett, K. T. and K. A. Otter. 2004. Presence of cavities in snags retained in forest cutblocks: do management policies promote species retention? Can. Field. Nat. 118: 354-359.</p> <p>1 - Very Relevant to Jackson WHMP</p> <p>Availability of nest sites often limits the population of cavity nesters.</p> <p>Some timber companies retain hardwoods and advanced regeneration trees within cutting units to increase structural diversity after harvest. This helps to reduce the distance that wildlife must travel through an open cutting unit.</p>

	<p>Forest dwelling species have been shown in several studies to be reluctant to cross gaps between fragmented forests:</p> <ul style="list-style-type: none"> ** forest birds were 3x less likely to cross gaps 70 m wide, and 8x less likely to cross gaps 100m wide versus similar distances in the forest. ** snags retained within the cutting unit may be less utilized simply because of the reluctance to cross open gaps from the forest edge. ** distance from forest edge had a inverse relationship on the frequency of cavities. **cavities were more common within the forest than the cut unit. **snags located farther from forest cover were underutilized. <p>Cavity nesters preferred deciduous trees for nesting, thus a high component of these trees should be maintained for the purpose of managing cavity nesting birds.</p> <p>***Highest density of cavities was within 100m of the edge.</p> <p>Class 2 & 3 snags have been found to have higher nesting success by primary cavity nesters.</p>
194	<p>Filip, G.M., Parks, C.G., Baker, F.A., Daniels, S.E. 2004, Artificial inoculation of decay fungi into Douglas-fir with rifle or shotgun to produce wildlife trees in western Oregon. W. J. Appl. Forestry 19(3):211-215.</p> <p>1 - Very Relevant to Jackson WHMP</p> <p>Study checked trees artificially inoculated with rifle/shotgun rounds 5 years post-treatment vs. those topped with saw:</p> <p>It appears that tree killing by topping below the live crown is a faster method of creating wildlife habitat than ballistic inoculation of live Douglas-fir trees in the Oregon Coast Range.</p> <p>Topped and deadtrees had more foraging holes, deep cavities, and bark 11removed than did live inoculated trees. Based on the seven shot trees that we sampled for internal decay, it appears that shooting trees with a shotgun or rifle is effective in creating internal decay within 5 years, but it may be take several more years to form a decay column large enough to be used by cavity-nesting birds.</p>
138	<p>Fox, T.J., M.G. Knutson, and R.K. Hines. 2000. Mapping Forest Canopy Gaps Using Air-Photo Interpretation and Ground Surveys. Wildl. Soc. Bul. 28:882-889.</p> <p>2 - Somewhat Relevant to Jackson WHMP</p> <p>Diversity of bird communities was found to increase as the number of canopy gaps increased, but excessive fragmentation can reduce reproduction rates of interior forest nesting birds at the stand and regional scales.</p> <p>Harvest practices modified to mimic naturally occurring gaps can help to maintain conditions required by native plants and animals.</p> <p>Air photos were found to be superior to ground surveys for recording number, location and shape of canopy gaps.</p> <p>Gap locations should be recorded as the intersection of the maximum length and max width axes.</p>

	<p>A gap 7-10 meters in diameter was the smallest diameter that could be discerned from air photos.</p>
188	<p>Gibbs, J.P., M. L. Hunter, Jr., and S. M. Melvin. 1993. Snag Availability and Communities of Cavity Nesting Birds in Tropical Versus Temperate Forests. <i>Biotropica</i> 25:236-241. 3 - Not Relevant to Jackson WHMP Simply compares availability of snags in tropical and sub tropical areas to temperate systems.</p>
292	<p>Gitzen, R.A. 1999. The Effects of Experimental Canopy Gaps on Small Mammal Communities in the Southern WA Cascades. Seattle, WA. Univ. of WA, Master's thesis. 125p. 1 - Very Relevant to Jackson WHMP Thesis available at UW Library</p> <p>Leaving small gaps during planting and creating small openings during thinnings may promote understory development.</p> <p>Gaps ranged from 1/1000th acre (0.004 ha) to 1/2 ac (0.20ha) and were 5-7 years old, with some 1 ha gaps from a concurrent study also examined. The small gaps are roughly equal to a single tree death. Gap sizes were relative to the canopy height. 1.0 gaps would be approx 50m diam in mature & old stands, and 35m in young stands.</p> <p>Stand age: 90yo = young, 140yo = mature, 500yo = old.</p> <p>Gaps increased low vegetation cover, but had not effect on tall shrubs and CWD.</p> <p>Only 1 species of small mammal (<i>Microtus oregoni</i>) showed a strong response to the gaps in terms of occurrence. <i>Sorex</i> spp. Trended toward lower abundance, possibly as a result of disturbance and soil compaction during mechanical gap creation.</p> <p>Lack of strong association between small mammals and gaps may be a result of territory size. The 0.2, 0.4 gaps in all stands and the & 0.6 gaps in young stands cover only a portion of the average home range size of many forest dwelling small mammals.</p> <p>Given the low sun angles in the Northwest, the relation of opening size to canopy height may be more important than actual gap size in determining vegetation response.</p> <p>If gaps fill in with hemlock or silver fir, resources required by small mammals may actually decrease.</p> <p>Forest gaps appear to increase resources for forest species, as opposed to recruiting early-successional species.</p> <p>Creation of gaps 30 to 50m in diameter may serve to increase populations of small mammals which in turn feed weasels and marten, but the small mammals may also affect seedlings survival.</p> <p>Shrub and herb production gaps may actually decrease in gaps if they fill in with hemlock or silver fir.</p>
171	<p>Gitzen, R.A. and S. D. West. 2002. Small Mammal response to Experimental Canopy Gaps in the Southern Washington Cascades. <i>For. Ecol. And Manage.</i> 168:187-199. 1 - Very Relevant to Jackson WHMP Gap sizes were created relative to the height of the overstory trees.</p> <p>Gaps that were 1.0 relative to canopy height in mature and old-growth stands were approximately 0.4 ac in size.</p>

	<p>Most closed-canopy species in western Washington are present after large-scale disturbances, and it appears that sharp changes in occurrence or abundance are unlikely in these small openings. The large gaps were roughly the size of only one to two home ranges for the small shrews, <i>Peromyscus</i>, and the southern red-backed vole.</p> <p>When such openings affect species composition, they frequently have done so by attracting early-successional specialists rather than by excluding forest species. Abundances of closed-canopy species generally have been similar or higher in openings than in forest controls.</p> <p>Due to aggressive responses by western hemlock and slow colonization and growth by <i>Vaccinium</i>, small disturbances in southeast Alaska coastal forests may actually decrease understory shrub and herb cover. In the western Cascades, gaps sometimes may be filled with dense regeneration of western hemlock or Pacific silver fir, potentially decreasing ground-level cover.</p> <p>For small mammals, most individual gaps probably have minor effects on abundances and no effects on species occurrence in the southern Washington Cascades. The extremely tall, narrow-crowned trees and low sun angle of the Pacific Northwest result in relatively subtle effects of small treefall gaps compared to dramatic changes associated with single-tree gaps in some tropical forests (Spies et al., 1990).</p> <p>Based on evidence from this study, creation of multiple small gaps in mature stands seems more likely to increase rather than decrease abundances of the relatively flexible closed-canopy species in western Washington.</p> <p>In forests similar to these sites, relatively large gaps or a large number of small gaps may be needed to increase species diversity by providing habitat for early-successional small mammals.</p>
104	<p>Gray, A. N., T.A. Spies and M.J. Easter. Microclimatic and Soil Moisture Responses to Gap Formation in Coastal Douglas-fir Forests. <i>Can. J. For. Res.</i> 32:332-343.</p> <p>1 - Very Relevant to Jackson WHMP</p> <p>Variations in the timing of gap creation, sizes of gaps and microsite differences contribute to the diversity of species within forests.</p> <p>Soil moisture in PNW forests is essential for tree reproduction, particularly from June to September is low (usually less than 20 cm).</p> <p>For this study, created gap diameters (measured between the tree crown edges) to tree height ratios of the four gap sizes were 0.2, 0.4, 0.6, and 1.0.</p> <p>*** Mean air temp in gap centers on sunny summer days was not significantly different among sizes of gaps.</p> <p>*** Gaps remained substantially wetter during summer than control plots. Gap centers were wetter than edges, which were usually wetter than the control forest.</p> <p>Centers of the smallest gaps (0.2 size gaps) dried more rapidly during summer than the 3 larger sized gaps.</p> <p>Northern portion of the 3 larger gap sizes were usually drier than the southern portion. Northern edges exhibited a negative response to gap formation, and southern edges a positive one. Regeneration of trees was reduced in these areas. Whereas the southern portions of the</p>

	<p>large gaps were cooler and wetter and allowed regeneration and growth of a wide variety of plant species.</p> <p>The most common gap size in coastal DF forests is 0.2</p> <p>*** Conifer seedling growth was 50% greater in the 0.2 gaps than in the forested controls.</p> <p>*** Canopy gaps increased solar radiation levels by double or more up to 20m beyond the northern edge of gaps. Thus, the effects of canopy gaps on forest processes is not limited to the opening alone.</p>
25	<p>Gray, A.N., Spies, T.A. 1996. Gap size, within-gap position and canopy structure effects on conifer seedling establishment. <i>J. Ecology</i> 84:635-645.</p> <p>1 - Very Relevant to Jackson WHMP</p> <p>Portions of large gaps with direct exposure to the sun had relatively low seedling establishment, particularly for Hemlock. All species were most abundant in the shaded portions of gaps.</p> <p>An increase in gap size corresponded to an increase in seedling size, being the greatest at gap centers.</p> <p>Douglas fir seedling growth was relatively low except in the largest gaps. Hemlock growth increased dramatically with gap size, and silver fir responded the least to gap size.</p> <p>Created gaps may help to accelerate the development of multiple canopy layers.</p> <p>Seedling density appears better related to gap age than to gap size.</p> <p>Both Hemlock and Silver fir can survive for many decades with little growth in shaded forests, and resume growth following a disturbance and concomitant increase in light levels.</p> <p>Contrary to common opinion, Douglas fir can germinate in shade or become established on intact forest floor.</p>
26	<p>Gray, A.N., Spies, T.A. 1997. Microsite controls on tree seedling establishment in conifer forest canopy gaps. <i>Ecology</i> 78(8):2458-2473.</p> <p>1 - Very Relevant to Jackson WHMP</p> <p>Species composition within gaps is likely determined by more than size and shape of the gap; fine scale environmental factors may also be important.</p> <p>Gap sizes were determined by gap diameter:tree height ratios, and were classified as 0.2, 0.4, 0.6 & 1.0</p> <p>Douglas-fir reproduces best on mineral soil in high-light conditions. Hemlock is shade tolerant, but appears to be so sensitive to competition from other understory vegetation while in the seedling stage that successful regeneration is usually limited to growing on decaying Douglas-fir logs.</p> <p>Silver fir is also shade tolerant, but is sensitive to both overstory and understory canopy density.</p> <p>*** Many gaps were found to be devoid of tree saplings more than 50 years after gap formation.</p> <p>For seedling establishment, gap size was marginally significant.</p> <p>Silver fir and Hemlock seedling establishment was greater in the 0.2 and 0.4 gaps than in controls and 1.0 gaps.</p> <p>Hemlock establishment in the 1.0 gaps were significantly lower than the other species.</p> <p>Seedling size increased with gap size.</p> <p>Particularly for silver fir, seedling establishment in the 1.0 gaps was greatest in 90% shade.</p> <p>Seedling survival for both Douglas-fir and hemlock was highest on decayed wood.</p>

	<p>Douglas fir tended to survive best in shady portions of the sunniest gap area (i.e. north edge) and in the more open portions of the smaller, darker gaps (i.e. south edge). The advantage that hemlock incurs from growing on decaying wood appears to decrease with gap size.</p>
190	<p>Gyug, L.W. and S.P. Bennett. 1995. Bird Use of Wildlife Tree Patches 25 Years After Clearcutting. In: Bradford, P., T. Manning and B. l'Anson eds. Wildlife Tree/ Stand-Level Biodiversity Workshop Proceedings. Victoria, B.C. October 1995. 15-33. 1 - Very Relevant to Jackson WHMP Study conducted in South-Central B.C.</p> <p>Wildlife tree patches were designated as "no-work" zones where snags did not have to be felled for worker safety.</p> <p>In one harvest area, 7% of the 160 ha harvest area was reserved in 12 seed tree patches, with a mean patch size of 0.9 ha (range 0.3 - 1.5 ha); mean inter-patch distance to neighbor was 203m.</p> <p>In another harvest area or 1000 ha, 29 seed tree patches were left (10% of harvest area). Mean patch size was 3.6 ha (range 1.6 - 18.9 ha). Mean distance between patches was 201m. Most patches were small (median 2.3 ha).</p> <p>Owls and woodpeckers were sampled in the harvest units 25 to 29 years post-harvest. No species of either were detected in clearcuts, some were found in forest patches, and all were found in the neighboring forest.</p> <p>The Pileated was absent from the patch areas and clearcuts.</p> <p>Hairy woodpecker, Northern flicker and red-naped sapsucker were found in the patch environments.</p> <p>Tree species, diameter and decay class were much more significant in determining woodpecker use of individual wildlife trees than the habitat.</p> <p>A majority of nests were found in snags greater than 75 cm dbh.</p> <p>Authors felt that wildlife tree patches were quite effective at mitigating the effects of clearcutting on many species.</p> <p>Only one cavity-nesting bird was found in the harvest units without reserve patches.</p>
244	<p>Hagar, J. 2006. Key elements of stand structure for wildlife in Pacific Northwest conifer forests. In Harrington, T.B., G.E. Nicholas, tech. eds. Managing for wildlife habitat in west-side production forests. Gen. Tech. Rep. PNW-GTR-695. Portland, OR:USDA Forest Service, Pac. NW Res. Stn. Pp.35-48. 1 - Very Relevant to Jackson WHMP Review article discusses key features: Large trees, e.g. wolf trees, remnant old growth trees. If evenly dispersed, large trees in otherwise unsuitable (i.e.harvested) areas can facilitate movement of forest interior spp. Options for recruiting, developing and maintaining large trees include retaining green trees at harvest, and growing them at reduced stand density to provide growing space for larger limbs and deeper crowns.</p> <p>Large dead wood. Size and decay stage matter. Habitat value increases with diameter, and a diversity of decay stages of snags and logs. Avg. diameter of snags used by all wildlife spp for nesting or denning exceeds 50 cm. Chipmunks selected logs that have larger avg diameters than randomly available wood to use at travel paths. Den sites for large animals (e.g. bear) are</p>

	<p>limited to logs of >80 cm.</p> <p>Current guidelines for augmenting volumes of woody debris in managed forests may be inadequate to maintain populations of all associated spp. (Rose et al 2001, Wilhere 2003). At least 10 snags >25 cm dbh per hectare recommended, (Hayes and Hagar 2002, Mellen et al 2006). Avg. diameter of snags used by cavity-using spp is >56 cm (Mellen et al 2006).</p> <p>Management strategy for spp associated with dead wood should ensure spatial and temporal continuity of habitat.</p> <p>**Retain existing large snags and logs during timber harvest</p> <p>**Plan for future recruitment of dead wood. Retained trees can be clumped in patches for safety and operational ease.</p> <p>**Use advisory tools, DecAID (Mellen et al 2006) and Coarse Wood Dynamics model (Mellen and Ager 2002) to plan dead wood management.</p> <p>Floristic diversity, in particular the presence of shrubs and hardwood trees, especially important for wildlife diversity. Literature shows consistent patterns of positive correlations b/n birds and abundance and distribution of hardwoods in conifer forests.</p> <p>"Hardwoods may be preferred by many species [of cavity-nesting birds and mammals] because wood properties and decay patterns often result in softened heartwood that is easily excavated, while the sapwood remains unaffected by decay...In contrast, sapwood of Douglas-fir snags often decays by the time heartwood is sufficiently softened for cavity excavation...Because of these differences, hardwoods can provide suitable cavity sites at relatively smaller diameters than conifers (Bunnell et al. 1999).</p> <p>Management of hardwoods should begin early in stand development. Controlling density at an early age, before canopy closure, can help to maintain diverse stand structure throughout the life of a stand (Tappeiner et al. 2002). Although shrubs may dominate early succession, it is unlikely that clear-cutting can be used to immediately create quality habitat for shrub-associated wildlife spp.</p> <p>Commercial thinning has the potential to increase habitat value for shrub-associated wildlife. (citations) Cover and productivity of shrub understory may respond positively to thinning. Variable density thinning may further enhance habitat by increasing spatial heterogeneity. Leave trees may be selected on the basis of characteristics such as cavities, large limbs. Etc. rather than spacing.</p> <p>Sites for shrubs and hardwoods minimize impacts of timber production may include seeps, wet depressions, small wetlands, riparian areas, road edges, landings, root rot pockets. Intentionally-managed canopy gaps could serve as sites for large trees, snags and floristic diversity.</p>
129	<p>Hansen, A.J., Spies, T.A., Swanson, F.J., Ohmann, J.L. 1991. Conserving biodiversity of managed forests. <i>Bioscience</i> 41(6):382-392.</p> <p>2 - Somewhat Relevant to Jackson WHMP</p> <p>Natural disturbance in unmanaged forests maintains structural complexity within stands, and this complexity promotes plant and animal diversity. This paper has a good discussion of the role natural disturbance and forest succession, including some data on snag and cwd densities in unmanaged forests.</p> <p>Recommendations for managed forests with biodiversity goals:</p> <p>Retain structural legacy from the preharvest stand, e.g. large trees in cutting units.</p> <p>Extend rotation ages.</p> <p>Produce new large trees, snags and CWD over the course of forest rotation.</p>

	Preserve herb/shrub stage.
89	<p>Harestad, A.S. and Keisker, D.G. 1989. Nest tree use by primary Cavity-nesting birds in South Central British Columbia. <i>Can. J. Zool.</i> 67:1067-1073.</p> <p>2 - Somewhat Relevant to Jackson WHMP</p> <p>Biogeoclimatic zone appears to be significantly different than our area. Nest trees were primarily Trembling Aspen and Paper Birch. Douglas fir and Hybrid Spruce were available but not used. This does, however, point to the need to preserve hardwoods wherever available for nesting & roosting opportunities.</p>
245	<p>Harrington, T.B. 2006. Silvicultural guidelines for creating and managing wildlife habitat in westside production forests. In Harrington, T.B., G.E. Nicholas, tech. eds. <i>Managing for wildlife habitat in west-side production forests</i>. Gen. Tech. Rep. PNW-GTR-695. Portland, OR:USDA Forest Service, Pac. NW Res. Stn. Pp. 49-60.</p> <p>1 - Very Relevant to Jackson WHMP</p> <p>Designing New Stands</p> <p>Pre-treatment planning required to identify appropriate treatment intensity, to retain existing structural elements, or provide conditions for development of new structural elements. Specific habitat features that can be retained or created:</p> <ul style="list-style-type: none"> **forage (mast, browse, or grazing) spp **nest sites **snags and green trees **shrub cover **CWD <p>Areas in harvest unit can be designated for wood production, combination of wood production and wildlife habitat, and habitat only, to avoid conflicting treatments.</p> <p>Cites WA DNR (2006) recommendations for snags:</p> <ul style="list-style-type: none"> **Locate snags away from trails, roads, buildings, etc. **Conifer snags last longer than hardwood snags; selected trees should have a stem diameter of at least 14 in to provide nest sites and for increased longevity. **Trees should be topped or girdled at or above the first whorl of branches, at least 14 ft above ground and ideally much higher. Smaller trees or stumps at least 3 ft tall may be useful for some cavity nesters **A jagged top decays faster **Artificial cavities, (6 in deep X 4 in high) accelerate decay in new snags **Large branches (2 ft long or more) provide foraging habitat **Roosting slits (angled upward at least 8 in deep and 8 in wide) are used by bats and some birds <p>Establishing Understory Conifers</p> <p>If goal is to manage understory conifers as a second story for habitat (and ultimately crop trees), recommends relatively low overstory. Overstory density should not exceed 20% of full stocking.</p> <p>Reduction in overstory density can result in excessive conifer regen. Can reduce regen via moderate soil disturbance during timber harvest or a subsequent pre-commercial thinning</p> <p>Promoting Understory Vegetation</p> <p>Thinning combined with moderate soil disturbance creates germination substrates for seedling regen of woody and herbaceous spp. Thinning Douglas-fir stands is followed by increases in seedling germination of salal, vine maple, huckleberry, tanoak, bigleaf maple, red alder, salmonberry, Pacific madrone. However, development of shrub cover and wildlife forage occurs much more rapidly from sprouts, which is the preferred method of regeneration.</p>

	<p>Thinning intensity and pattern influence spatial distribution of woody debris and soil disturbance. In the DEMO study, depth and cover of debris were greater at the highest thinning intensity and in aggregated vs. dispersed retentions of overstory trees (Halpern and McKenzie 2001).</p> <p>Using thinning to create old-forest structure</p> <ul style="list-style-type: none"> **Retain large trees from previous stand, especially those with large limbs, cavities and rough bark **Retain minor spp including Sitka spruce Engelmann spruce, yew **Create seedbeds for establishment of understory plants, via soil disturbance (e.g. skidding of logs) **Control understory competition when it becomes excessive. A dense understory of shrubs like salal, vine maple, salmonberry, huckleberry or blackberry; hardwoods like bigleaf maple, can interfere with seedling establishment of conifers and otherspp. In these cases, it may be necessary to control shrubs and hardwoods, and plant conifer seedlings to establish a multi-storied stand. **Manage some trees or parts of stands at low density, via thinning around selected trees in order to provide space, maintain large crowns and continue rapid diameter growth. <ul style="list-style-type: none"> **Use thinning to favor patches of regeneration. Thinning can be concentrated around patches of advanced tree regen to facilitate development of multi-storied stands. **Allocate trees for production of snags and CWD See DecAID guidelines to produce appropriate abundances and sizes of woody debris **Relatively dense overstories favor some herbaceous spp. Maintaining dense patches of overstory trees or excessive conifer regen may retard establishment of a dense shrub cover, and provide sites for late-seral herbaceous plants (Lindh 2005). **Large (>40 in diameter) old (>200 yrs) trees will respond positively to thinning. **Create space for hardwoods. Reduce conifer density around hardwood to maintain full vigorous crowns. Recommends heavy thinning around 0.25 to 0.6-ac patches of hardwoods. <p>Opportunities to do these things occur sporadically in stands, therefore, density will be spatially variable. E.G. if the goal is to grow 30 large trees/ac, the range might be >40 trees in some areas and <10 trees elsewhere, with an avg. of 30 trees over an area of 5 to 10 ac.</p> <p>Information needs for planning stand development:</p> <ul style="list-style-type: none"> **Sizes, densities and spp comp of large overstory trees and second-story trees needed to produce multi-storied stands. **Stand density or gap size needed to grow understory trees **Sizes and densities of existing snags and CWD **Effects of snow, wind, insects and pathogens on tree mortality and the associated production of snags, logs on the forest floor, and cavities. <p>Tree and stand responses to thinning.</p> <p>At the stand level, thinning reduces competition for light, water and nutrients, thereby increasing the growth of overstory trees and the abundance of understory plants.</p> <p>A major response of trees to thinning is increase in crown size. Tree crown height increases as lower branches survive and height growth continues. As crown length increases, stem diameter increases on the lower part of the stem: the tree's stem becomes more tapered and more resistance to windthrow or stem breakage. An increase in diameter may occur within 3 to 5 yrs. Epicormic branching in Douglas-fir produces fan-like branches using for roosting by birds and rodents.</p> <p>Caveats.</p> <p>Treating stands once with a single heavy thinning might create a dense shrub (or conifer) understory with low diversity. Thinning around hardwoods would then be necessary. Suggests conducting light thinning to begin the process and develop options for future</p>
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	<p>development. E.g. the initial treatment might enable reprod in the understory and begin development of large trees. A 2nd thinning would release the understory trees and provide for continued growth of large trees.</p> <p>Thinning leads quickly to understory density, and conifer regen. Immediate benefits to wildlife. Other old forest attributes, like large cavities, nesting platforms on large limbs, or high abundance of CWD, will take decades to develop.</p>
302	<p>Harris, M. 2004. The Importance of Competition Processes and Canopy Gaps in the Development of Old-Growth Pseudotsuga/Tsuga Forests. Seattle, WA: Univ. of WA. Master's Thesis; 101p. 1 - Very Relevant to Jackson WHMP Available from UW library</p> <p>Notes a study that found light to be the most important factor in limiting seedling growth when PAR (photosynthetically active radiation) was less than 30% of full sun.</p> <p>Notes several studies that found no association between canopy openings and regeneration on the forest floor.</p> <p>Notes a study that found that canopy gaps were important for allowing regeneration of Tsuga and Abies establishment under Tsuga canopies, but not needed for regeneration of shade tolerant species beneath Pseudotsuga canopies.</p> <p>Due to the incidence of light angles at this latitude, locations of regeneration may be associated with canopy gaps, but may not be superimposed on the same location.</p> <p>Notes study (Parker et al 2002) that found that large gaps extending from the upper canopy to the understory are not necessarily associated with a large increase in light directly beneath the gap.</p> <p>Competition induced mortality appears to be higher between Tsuga and Abies in more open areas; but appears minimal among Tsuga regeneration on nurse logs in an area with many canopy trees and few gaps.</p>
293	<p>Hartwig, C.L. 1999. Effect of Forest Age, Structural Elements, and Prey Density on the Relative Abundance of Pileated Woodpecker (<i>Dryocopus pileatus</i>) on Southeastern Vancouver Island. Victoria, British Columbia, Canada. Univ. of Victoria. Master's Thesis. 1 - Very Relevant to Jackson WHMP Copy available on microfiche from U of Victoria.</p> <p>Relative abundance of PWP was not significantly different in landscapes with 51% of >140 yo stands (greatest rel. ab.); imm forests with 49% >80yo; or forest with 70% >140 yo.</p> <p>Snags & decadents used for foraging were larger (56cm dbh mean), more decayed, less bark (49% mean) and were in the upper and main canopy strata versus those not used for foraging.</p> <p>Foraging areas also had mean CWD of 192 +/-26 SE cubic meters/ha. Logs used for foraging were larger, longer and less decayed than those not used.</p> <p>Cedar was also more common in areas used for foraging.</p> <p>Mean ht of cavities was 22 +/- 5.2 SE m Nesting trees mean dbh = 82 +/- 16 SE cm, mean ht 22 +/- 5.2 SE m, and 91% +/- 9 SE bark remaining.</p> <p>Nest and roost sites had significantly greater basal area of snags and defectives (mean 7.6 +/-</p>

	<p>1.0) sq m/ha.</p> <p>Study area SE Vanc Island</p> <p>Calls were most frequently heard within 1 hour after sunrise, and decreased for 5 hours, then began to rise again slightly.</p> <p>Snags > 45-57.49 cm and > 57.49 were used more than available.</p> <p>Neither CWD or snag mean sizes or preferred sizes were <38cm for snags and <25 cm for CWD.</p> <p>Cedar and alder were selected for by PWP.</p> <p>Douglas fir and maple were used in proportion to availability.</p> <p>An average of 7 different roost trees are used by each bird in a 3 to 10 month period.</p> <p>Habitat at nest plots had significantly more basal area, older structural stage, older successional stage, & less disturbance than habitat at unused sites.</p> <p>Nest and roost trees were significantly larger and taller than most other trees.</p> <p>Of studies reviewed for this manuscript, the NW WA cascades reported the largest mean nest tree sizes (100.5 cm dbh) Aubry & Raley 1995. This is likely due to more moisture leading to better growing conditions.</p> <p>Nest trees in WA were the tallest (39.5m) widest (100.5 cm dbh) and had the highest nests (35.2m) of all N Am studies.</p> <p>Areas with forest >80 yo, high snag densities, high CWD volumes had higher prey densities for PWP and higher abundance of PWP.</p> <p>An inadequate supply of nest snags for PWP may result in them re-using the same tree in subsequent years, thereby reducing the number of cavities available for secondary cavity nesters.</p> <p>Research focused on the highest densities or on optimum suitability have recommended higher snag numbers (30-50/ha),</p> <p>Basal area of snags (>20 dbh) in foraging areas was 7.5 (+/- 1.1 SE) sq m/ ha; roughly equal to 28 snags of 56cm dbh/ha.</p> <p>Recommends leaving snags in moderately dense clumps, not evenly distributed across the landscape.</p>
16	<p>Hartwig, C.L., D.S. Eastman and A.S. Harestad. 2002. Forest age and relative abundance of pileated woodpeckers on southeastern Vancouver Island. In: Laudenslayer, W.F. et al. eds. Proc. Of the Symposium on the Ecology and Management of Dead Wood in Western Forests. PSW-GTR-181. pp. 247-256.</p> <p>2 - Somewhat Relevant to Jackson WHMP</p> <p>PWP did not use managed forests <80 years old that had low densities of large snags & logs.</p>
168	<p>Hartwig, C.L., D.S. Eastman and A.S. Harestad. 2003. Characteristics of Pileated Woodpecker (<i>Dryocopus pileatus</i>) Cavity Trees and Their Patches on Southeastern Vancouver Island, BC, Canada. For. Ecol. And Manage. 187:225-234.</p>

	<p>1 - Very Relevant to Jackson WHMP</p> <p>Nest trees are considered the limiting factor for most populations of pileated woodpeckers (Bull and Jackson, 1995), and so in managed forests, there is a need to ensure that these trees are not removed during timber harvesting and other forestry activities.</p> <p>Cavity trees were significantly larger in diameter (78 +/- 6 cm) than trees without cavities (47 +/- 2 cm). As well, they were taller and comprised a larger proportion of the trees in the upper canopy and above canopy classes.</p> <p>Western hemlock had less canopy cover in cavity patches, while big leaf maple and grand fir had greater canopy coverage. No significant differences in cover were found for Douglas-fir, western red cedar and red alder.</p> <p>PWP habitat patches with cavity trees had slightly fewer Hemlock, but significantly more big leaf maple and grand fir.</p> <p>Of the major studies of pileated woodpecker, the Cascade Mountains of northwestern Washington had the largest mean dbh of nest trees at 100 cm (Aubrey and Raley, 1995). This likely reflects the availability of large trees at their site which were, on average, larger than those in our study area. Harestad and Keisker (1989) reported the smallest mean dbh of any North American study at 40.5 cm in southcentral British Columbia. This small size of nest trees likely reflects the relatively small size of trees available in their study area.</p> <p>The broad range in diameters of trees used by pileated woodpeckers for nesting indicates flexibility in nest tree selection. However, in all published studies, pileated woodpeckers select the larger trees of those available and thus reveal a consistent preference for large-diameter trees for nesting. Such preference probably relates to their need for suitably sized nest chambers in which to raise young.</p> <p>Nest trees in western Washington were the tallest (40 m) and had the highest nests (35 m).</p> <p>Nest trees are less likely to occur in clear cut or patch-retention treatments (Gyug and Bennett, 1995).</p> <p>In addition to retaining suitable large trees, it is important to reserve stands with a greater proportion of big leaf maple and grand fir (and less western hemlock), in mature or older structural stages and mature climax successional stages.</p>
225	<p>Hartwig, C.L., Eastman, D.S., Harestad, A.S. 2006. Characteristics of foraging sites and the use of structural elements by the pileated woodpecker (<i>Dryocopus pileatus</i>) on southeastern Vancouver Island, British Columbia, Canada. <i>Ann. Zool. Fennici</i> 43:186-197.</p> <p>1 - Very Relevant to Jackson WHMP</p> <p>Until recently, feeding habitat had not been considered as important as nesting habitat for PWP because any woody debris >18 cm was considered available for feeding year round.</p> <p>Additional research points to selection for much larger trees than previously thought in many areas, including WA.</p> <p>Snags and defective trees used for foraging were larger, more decayed, and had significantly less bark and fewer limbs than those not used.</p> <p>Used snags and defectives were significantly larger in mean dbh than unused ones. The numbers of snags used in the two largest dbh classes were significantly greater than those in all other classes of snags and defectives that were used.</p>

324	<p>Hayes, J.P., Hagar, J.C. 2002. Ecology and management of wildlife and their habitats in the Oregon Coast Range. In: Hobbs, S.D., Hayes, J.P., Johnson, R.L., Reeves, G.H., Spies, T.A., Tappeiner, J.C. II, Wells, G.E., eds. Forest and stream management in the Oregon Coast Range. Corvallis, OR: OSU Press. P. 99-134.</p> <p>2 - Somewhat Relevant to Jackson WHMP</p> <p>Current guidelines for augmenting volumes of woody debris in managed forests may be insufficient to maintain populations of all species associated with dead wood. For example, the Oregon Forest Practices Act Standards for wildlife trees (5 snags or green trees per hectare) represents the lowest end of the natural range of snag densities, and is well below the densities associated with use by cavity-nesting wildlife (at least 10 snags that are at least 25 cm dbh per hectare).</p>
296	<p>Holtrop, Karen. 2007. Phone conversation on behalf of Olympic National Forest, Quilcene Ranger District. May 22, 2007.</p> <p>1 - Very Relevant to Jackson WHMP</p> <p>Create 1 snag/acre in recent commercial thinning areas, with a plan to re-enter and create more in the future if necessary.</p> <p>Use a chainsaw to either top or high-girdle at 50-90'</p> <p>Use Forest Service DecAID model as a goal, but are usually well below that.</p> <p>Use landscape level approach, manage snag densities across entire watersheds.</p> <p>The old forest plan (1990) for the Olympic NF called for 3/ac.</p> <p>They aim for 80% population levels across the landscape.</p>
126	<p>Huff, M.H., D.A. Manuwal, and J.A. Putera. 1991. In: Ruggiero, L. F. et al, editors. Wildlife and Vegetation of Unmanaged Douglas-fir Forests. USDA Forest Service, GTR-PNW-285. pp 207-218.</p> <p>1 - Very Relevant to Jackson WHMP</p> <p>see supporting link</p>
155	<p>Hunter, J.E. & M. L. Bond. 2001. Residual Trees: Wildlife Associations and Recommendations.</p> <p>3 - Not Relevant to Jackson WHMP</p> <p>Primarily focuses on retention of residual trees in logging units of coastal southern California/ Redwoods area.</p>
172	<p>Huss, M.J., J.C. Bednarz et al. 2002. The Efficacy of Inoculating Fungi into Conifer Trees to Promote Cavity Excavation by Woodpeckers in Managed Forests in Western Washington. Gen. Tech. Rep. PSW-GTR-181. Albany, CA. Pacific SW Res. Stn, USDA Forest Service, pp. 777-794.</p> <p>2 - Somewhat Relevant to Jackson WHMP</p> <p>Article notes the beginning of a study to inoculate trees with fungi and track over time to measure the development of fungal basidiocarps and heartwood rot.</p> <p>Three years post-initiation, the results demonstrate that the fungal inoculations are largely successful (greater than or equal to 50 percent to 70 percent success) in introducing the desired fungus into both western hemlock and Douglas-fir.</p>
183	<p>Hutto, R. L.. 2004. Toward Meaningful Snag-Management Guidelines for Post fire Salvage Logging in North American Conifer Forests. Cons. Biol. 20:984-993.</p> <p>3 - Not Relevant to Jackson WHMP</p> <p>Describes post-fire salvage logging recommendations.</p>
243	<p>Irwin, L.L., D.F. Rock and G.P. Miller. 2000. Stand Structures Used by Northern Spotted Owls in</p>

	<p>Managed Forests. J. Raptor Res. 34: 175-186.</p> <p>Comparison of vegetation in forest stands in foots of w Cascades in Oregon using for nesting and foraging by spotted owls.</p>
137	<p>Jack, S.B., Parks, C.G., Stober, J.M., Engstrom, R.T. 2003. Inoculating red heart fungus (<i>Phellinus pni</i>) to create nesting habitat for the red-cockaded woodpecker. Proceedings, Red Cockaded Woodpecker Symposium, Jan. 2003, Savannah, GA. 18 p.</p> <p>3 - Not Relevant to Jackson WHMP</p> <p>Study results from sw Georgia involving southern pine species. Initial trial setup described.. Discussion of merits of artificial cavities vs. introduction of red heart fungus into trees. There is evidence that the inoculation process promotes the conversion of sapwood to heartwood through the compartmentalization process (see Rayner, A.D.M., , Boddy, L. 1988. Fungal decomposition of wood - its biology and ecology. John Wiley and Sons, New York,. 567 p..</p>
173	<p>Joy, J.B. 2000. Characteristics of Nest Cavities and Nest trees off the Red-Breasted Sapsucker in Coastal Montane Forests. J. Field Ornithol. 71:525-530.</p> <p>1 - Very Relevant to Jackson WHMP</p> <p>No nest cavities were reused in the second year</p> <p>Mean DBH of nest trees was significantly greater than that of non-nest trees >17 cm dbh ($t=10.54$, $df=125$, $P<0.001$, Fig. 2.). Mean nest tree height ($\bar{x}=32.5$ m ± 2.4 SE, $n=31$, range 16.8–47.1) was also significantly greater than the mean height of random trees ($\bar{x}=14.75$ m ± 0.81 SE, $n=88$, $t=10.45$, $df=118$, $P<0.001$). The distribution of wildlife tree classes differed significantly from expected ($G=23.95$, $df=6$, $P<0.05$, Fig. 3). Sapsuckers selected only dead trees.</p> <p>Nest height averaged 17.2 m and was positively correlated with tree height ($r=0.55$, $df=30$, $P<0.001$).</p> <p>Red breasted Sapsuckers consistently chose nest trees of larger diameter than non-nest trees, as has been found with other sapsuckers (Dobkin et al. 1995) and other small woodpeckers.</p> <p>Red-breasted Sapsuckers require large nest cavities to accommodate large clutches and up to six nestlings (Campbell et al. 1990).</p> <p>Rates of predation and nest failure decrease among cavity nesters with increasing nest height (Nilsson 1984, Li and Martin 1991).</p>
53	<p>Keisker, D.G. 1986. Nest tree selection by primary cavity-nesting birds in south-central British Columbia. Burnaby, BC. Simon Fraser University. M.S. Thesis. 67p.</p> <p>3 - Not Relevant to Jackson WHMP</p> <p>Thesis produced in 1987, from south-central BC, where the 3 primary tree species were aspen, birch and alder.</p>
163	<p>Kellam, J. S. 2003. Pair Bond Maintenance in Pileated Woodpeckers at Roost Sites During Autumn. Wilson Bul. 115: 186-192.</p> <p>3 - Not Relevant to Jackson WHMP</p> <p>Study conducted in Maine.</p>
239	<p>Klinka, K., H.Y.H. Chen, Q. Wang and L. de Montigny. 1996. Forest Canopies and Their Influence on Understory Vegetation in Early-Seral Stands on West Vancouver Island. Northwest Sci. 70: 193-200.</p> <p>1 - Very Relevant to Jackson WHMP</p>

	<p>Cover of salmonberry is strongly related to canopy cover, but not canopy species.</p> <p>While canopy cover has a strong influence on the understory vegetation, other factors including site quality, pre-disturbance vegetation, and type of disturbance have a greater influence on the understory composition.</p> <p>Both salmonberry and salal increased in the understory as the canopy cover decreased, and both were shaded out when canopy cover was 85%+</p> <p>***For lands where wildlife habitat improvement and wood production are the goals, forests on moist/very moist, rich/very rich soils should be opened to provide more light to understory when canopy closure reaches 80%.</p> <p>***Reducing canopy closure to 60% would result in 40% salmonberry cover. Canopy should be non-uniformly opened.</p>
102	<p>Knutson, K.L. and V. Naef. WDFW, June 1995. SNAGS: Management Recommendations for Washington's Priority Habitats. 137p.</p> <p>1 - Very Relevant to Jackson WHMP</p> <p>Bernice, this doc has brief mentions of Riparian buffers, CWD, etc.</p> <p>Mike's review:</p> <p>Westside forests containing 4 snags/acre or more that are greater than 20" dbh are considered Priority Habitat.</p> <p>Approx. 102 species in Washington use snags; 56 species nest or den solely in cavities within dead or dying trees.</p> <p>*** the following 14 cavity-nesting species are Priority Species,</p> <p>***** Northern Spotted Owl is listed as endangered;</p> <p>***** The Pileated WP and Vaux's Swift are both Candidate Species for listing.</p> <p>***** The remainder are Priority Species, considered for listing:</p> <p>flamulated owl, purple martin, western bluebird, fisher, wood duck, Barrow's Goldeneye, common goldeneye, bufflehead, hooded merganser, marten and western gray squirrel.</p> <p>*** Natural ecosystems should provide the model for determining suitable numbers and characteristics of desired snags, i.e. average density and size found in unmanaged old-growth forests should serve as the targets for snag retention. Diverse, abundant and stable communities of snag-using species occur in unmanaged forests, particularly late-successional stands. Past use of minimums as standards has resulted in less habitat being provided than necessary, and hence continued population declines.</p> <p>Only old-growth stands were found to support 100% of the maximum potential population of primary cavity-nesters, so managing for averages based on these areas provides the best hope of retaining and increasing populations of snag dependent wildlife. Without such measures, the 56 cavity-dependent wildlife species will likely continue to decline in number, and may be listed as threatened or endangered.</p> <p>*** Models (i.e. Thomas et al. 1979) that have been used for the past 15 years have several problems, they only consider nesting requirements, not foraging or roosting and therefore appear to underestimate the number of snags needed.</p> <p>*** Additionally, these models may underestimate by assuming that meeting the needs of primary cavity excavators also meets the needs of other snag dependent species. In fact, secondary users may be more sensitive to snag densities than the primary nesters.</p>

	<p>Snags should be retained both individually and in clumps (including live trees and existing snags), if possible, and should be well distributed across the landscape. Clumps reflect the natural pattern of trees dying in patches from insects, small fires and disease. Clumping may also help to reduce impacts on logging operations.</p> <p>Artificial snag creation should not take the place of retaining existing snags.</p> <p>Snags in riparian areas are particularly important because several cavity-nesting species (wood duck, osprey, pileated wp) preferentially breed close to streams and wetlands.</p> <p>As a group, cavity-excavators prefer trees greater than 24 m (79ft) tall.</p> <p>Snags in decay stages 2-4 (7-125 yrs old) are most commonly used for nesting. At the start of stage 4 (51 years old) nesting use begins to decrease.</p> <p>Douglas-fir are the most commonly used nesting tree, but are also the most available in larger size classes. They tend to decay from the outside in and are favored by weak excavators. Hemlock are more susceptible to heart rot and are therefore more attractive to woodpeckers, but stand for a shorter period.</p> <p>Hardwoods tend to grow in irregular shapes and can produce cavities in the trunk or branches even while alive. Since they are much less common than conifers, they are particularly valuable wherever they are found.</p> <p>Audubon Society Christmas bird counts over 30 years have shown a decrease in the populations of the downy and hairy woodpeckers, as well as the northern flicker.</p> <p>Diameter is the most important distinguishing characteristic of snags used for nesting and foraging. Snags and decadent trees greater than 38 cm (15in) dbh are used by some species for nesting and foraging, larger diameter snags (>51 cm/20in dbh) are preferred and offer optimal nesting and foraging conditions. Taller snags are also preferred (>18m/59ft).</p> <p>When creating snags, trees should be topped (chainsaw was shown to be the most effective method) 15-25m (50-82ft) above the ground. Wind firm conifers at least 51 cm (20 in) dbh should be selected. Live trees should be reserved around the created snags to provide better protection for the snag as well as higher wildlife use.</p> <p>Retaining live green trees around created snags in harvested areas also moderates the microclimate and thus encourages seedling and shrub growth as well as increasing wildlife use of the clearcut.</p> <p>Contrary to common opinion, retained trees do not act as a source of pests for the new developing forest. They actually serve as refuge and inocula for invertebrate fauna and mycorrhiza-forming fungi that are essential components of a new stand.</p> <p>Riparian Habitat Area Minimum Widths are reported in Table 4 of the document.</p> <p>Salvage logging should not be conducted if an area is being managed for the benefit of wildlife.</p> <p>Link below is to App B showing averages and minimums for snags in the Western Hemlock series (when using this table, Mark Hitchcock reports the following, Lake Chaplain is 70% site class 2, 25% class 3 and 5% class 1; Spada is 60% site class 3, 30% class 4, and 10% class 5)</p> <p>****SEE ALSO Y:\Regulatory Affairs\WILDLIFE\Relicensing_Study_Plans\SP6 Literature Review\Supporting</p>
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	<p>Documents\Summary of Findings SP6 - Snags.xls</p> <p>AND</p> <p>Y:\Regulatory Affairs\WILDLIFE\Relicensing_Study_Plans\SP6 Literature Review\Supporting Documents\102 WDFW Snag Mgmt Recommendations App B.pdf</p>
237	<p>Lehmkuhl, J. F., S.D. West, C.L. Chambers et al. 1999. An Experiment for Assessing Vertebrate Response to Varying Levels and Patterns of Green-tree Retention. Northwest Sci. 73: 45-63.</p>
122	<p>Lewis, J. C. and J. M. Azerrad. 2003. Pileated Woodpecker. Pages 29-1 – 29-9 in E. Larsen, J. M. Azerrad, N. Nordstrom, editors. Management Recommendations for Washington's Priority Species, Volume IV: Birds. Washington Department of Fish and Wildlife, Olympia, Washington, USA.</p> <p>1 - Very Relevant to Jackson WHMP</p> <p>Most nests are in hard snags with intact bark and broken tops, or live trees with dead tops.</p> <p>PWP may use up to 11 roosts over a 3-10 month period.</p> <p>Cedar are often preferred as roost trees due to natural hollowing.</p> <p>Mature and OG forest are considered high quality habitat, but forests as young as 40 years are used if large residual snags are present.</p> <p>Shelterwood cuts and clearcuts are occasionally used if substantial foraging habitat is retained.</p> <p>Deciduous riparian habitat is used for foraging activities.</p> <p>Large snags are preferred foraging substrate, possibly because they harbor more insects and larvae than smaller snags.</p> <p>CWD is rarely used for foraging in wet coastal forests.</p> <p>Forest fragmentation may reduce population density and increase vulnerability to predation as the birds are forced to fly between fragmented forest stands.</p> <p>Management activities should focus on providing and maintaining large snags and large decaying live trees for nesting and roosting.</p> <p>Retaining snags and decaying live trees provides suitable nesting and roosting structure for a longer period than retaining/creating only hard snags.</p> <p>Trees, snags and stumps with existing PWP nest cavities and foraging excavations should be retained.</p> <p>Uneven-aged forest management can help to provide large trees and suitable canopy closure to maintain suitable nesting and roosting structure for PWP.</p> <p>Defective and cull trees should be retained during harvest operations.</p> <p>Extending harvest rotations may be one of the most effective means of providing large snags.</p> <p>Average values of given habitat components should be used as management goals.</p> <p>"Adequate snag densities are defined as the combination of nesting, roosting and foraging snag numbers"</p>

	<p>*** Recommendations: see supporting link</p>
123	<p>Lewis, J. C., M. Whalen, and R.L. Milner. 2002. Vaux's Swift. Pages 25-1 – 25-5 in E. Larsen, J. M. Azerrad, N. Nordstrom, editors. Management Recommendations for Washington's Priority Species, Volume IV: Birds. Washington Department of Fish and Wildlife, Olympia, Washington, USA. 1 - Very Relevant to Jackson WHMP Vaux's Swift are highly dependent on large hollow trees and snags for nesting and roosting.</p> <p>Availability of these structures is suspected to be the limiting factor for this species.</p> <p>They require large hollow chambers in large snags or live trees for nesting and night roosting.</p> <p>Nest trees average 82' tall, and 27" dbh</p> <p>They rely on Pileateds for creation of nesting and roosting habitat.</p> <p>*** Recommendations:</p> <p>Leave all hollow snags and live trees intact (preferably > 20" dbh); Large defective trees, especially those with top rot, broken tops, other signs of rot or defects should be retained.</p>
196	<p>Lewis, J.C. 1998 Creating snags and wildlife trees in commercial forest landscapes. W. J. Appl. Forestry 13(3):97-101. 2 - Somewhat Relevant to Jackson WHMP Primarily provides a summary of costs for different techniques of snag tree creation.</p>
101	<p>Lundquist, R.W. And J.M. Mariani. 1991. Nesting Habitat and Abundance of Snag-Dependent Birds in the Southern WA Cascade Range. In Wildlife and Vegetation of Unmanaged Douglas-fir Forests. USDA Forest Service, PNW-GTR-285. p 221-239. 1 - Very Relevant to Jackson WHMP For primary and secondary cavity nesters, the mean DBH of all active nest sites was 76 cm (range 18-167cm), and mean tree height was 25m (3-60m range). Mean nest tree diameters for all bird species were greater than 50cm. Snags in this size class were used disproportionately compared to availability in all forest age classes. Vaux's swifts were also found to use very large live trees and large snags. This study reports mean nest tree diameters that are larger than most other studies from the Olympic Peninsula, but smaller than the Oregon Coast Range. Nest sites contained higher densities of large, hard snags, concurring with other, earlier studies.</p> <p>***Mean nest tree diameters should be used as guidelines for management. Managing for minimums could cause gradual decline in cavity-nesting populations.</p> <p>***Recommend managing for snags with a minimum diameter of 76cm (the mean dbh of all active nests found).</p> <p>Snags 50cm dbh or greater should be given top priority in managing for cavity- and bark-nesting birds since this size is selected for disproportionate to its availability.</p> <p>By selecting the largest snags available, they will remain standing longer, retain bark longer and support of larger variety of wildlife.</p> <p>***Using the guidelines of Nitro 1985 would result in vastly underestimating the hard snags required west of the Cascades.</p>

	Retaining more than the minimum required amount of snags allows for unforeseen loss due to windthrow as well as uncertain fall rates of snags.
208	Maguire, C.C. 2002. Dead Wood and the richness of small terrestrial vertebrates in southwestern Oregon. Gen. Tech. Rep. PSW-GTR-181. USDA Forest Service. Pp. 331-345.
33	Marcot, B.G, Gunderson, G, Mellen, K., Ohmann, J.L. 2004. DecAID Advisor: a tool for managing snags, down wood and wood decay in forests of Washington and Oregon. Western Forester 49(4):12-13.
100	<p>Marcot, B.G. Annotated Review of Selected Literature on Snag Distribution. USDA Forest Service, PNW Region, July 17, 1988.</p> <p>1 - Very Relevant to Jackson WHMP</p> <p>Summary of selected literature on snag recommendations:</p> <ul style="list-style-type: none"> - Clumping snags in small patches enhances nesting habitat for the pileated woodpecker and other cavity nesting species. - The density and diversity of snags should be as great as possible, with the existing snag resource in an old, natural stand settings the upper limits (i.e. 11 snags/ha greater than 48cm dbh & 4.4m tall). - Retaining or creating large snags (greater than 60cm dbh & 15m tall) should receive particular emphasis. - Evenly distributed and clumped snag patterns best mimic natural conditions. - Managing for 100% population levels requires about 7 snags/acre, as this is what is seen in unmanaged forests. - Soft snags should not be counted, only large, hard snags. - A minimum level of snags to be left in a harvest unit should be set in addition to the background level of 7/ac, (i.e. on a 50 acre unit, 8-10% should be left in one snag habitat island).
32	Marcot, B.G. 2004. Wood decay in healthy forests: the paradox and the promise. Western Forester 49(4):4-5.
34	Marcot, B.G., Mellen, K., Livingston, S.A. 2002. The DecAID advisory model: wildlife component. In: Laudenslayer, R.F., J., Shea, P.J., Valentine, B.E., Weatherspon, C.P., Lisle, T.E., tech. coords. Proc. Symp. On the ecology and management of dead wood in Western forests. PSW-GTR-181. Berkeley, CA: USDA Forest Service, Pac. SW Res. Stn. 561-590.
66	<p>Marcot, B.G., Mellen, K., Ohmann, J.L., Waddell, K.L., Willhite, E.A., Hostetler, B.B., Livingston, S.A., Ogden, C., Dreisbach, T. 2003. DecAID Decayed Wood Advisor.</p> <p>1 - Very Relevant to Jackson WHMP</p> <p>Advisory tool to help managers evaluate effects of forest conditions and existing or proposed management activities on organisms that use snags and down wood. Advises on snag and CWD sizes and levels needed to help meet wildlife management objectives.</p>
124	<p>Marcot, B.G., R.S. Holthausen, J. Teply and W.D. Carrier. 1991. Old-Growth Inventories: Status, Definitions, and Visions for the Future In: Ruggiero, L. F. et al, editors. Wildlife and Vegetation of Unmanaged Douglas-fir Forests. USDA Forest Service, GTR-PNW-285. pp 47-60.</p> <p>1 - Very Relevant to Jackson WHMP</p> <p>Provides definitions of Old-growth characteristics, cited by several authors as the basis for managing for PWP.</p> <p>Society of American Forests -</p> <p>25+ snags/ha > 6m tall.</p> <p>10+ snags/ha > 64cm dbh</p>

	<p>Old growth Definition Task Force - 10+ snags/ ha > 51 cm dbh and > 4.6m tall.</p>
162	<p>Martin, S.K., Barrett, R.H. 1991. Resting site selection by marten at Sagehen Creek, California. <i>Northw. Naturalist</i> 72:37-42.</p> <p>2 - Somewhat Relevant to Jackson WHMP</p> <p>Study results from California:</p> <p>"Preserving large snags and logs for marten and leaving cull logs after timber harvest should benefit marten." "Average densities (no. per ha) in known marten habitat in our study were 46 snags, 66 stumps, and 39 logs." "The diameter of snags, stumps, and logs left for marten should be 80 cm or greater. Snags should be at least 4m tall, stump heights at least 80 cm and log lengths at least 10 m."</p>
230	<p>Mathiasen, R.L. 1996. Dwarf Mistletoes in Forest Canopies. <i>Northwest Sci.</i> 70:61-71.</p> <p>1 - Very Relevant to Jackson WHMP</p> <p>Spotted Owls, marbled Murrelet and several species of squirrels have been found to frequently use mistletoe brooms for nesting.</p> <p>Marten use brooms as resting sites.</p> <p>Sites with mistletoe are suspected of having much greater species diversity than mistletoe free sites.</p> <p>Studies in Colorado have shown that the number and abundance of passerine birds as well as cavity nesting birds is higher in these areas than in non-infested areas. Elk and deer activity was also higher in these stands.</p> <p>A more extensive list of species that are not rare or endangered and also use brooms is provided as well.</p>
174	<p>McDonald, P.M. and P.E. Reynolds. 1999. Plant Community Development After 28 Years in Small Group-Selection Openings. Research Paper PSW-RP-241. Albany, CA: PSW Res. Stn. USDA Forest Service; 17p.</p> <p>In 1963, small openings (9, 18 & 27 m diameter, measured from drip-line to drip-line) were created by timber harvest, with ground scarification to reveal bare mineral soil and virtually no competing vegetation.</p> <p>In larger openings and on south aspects, plants developed better and more plants were able to establish.</p> <p>Between the 11th and the 28 year post-initiation:</p> <ul style="list-style-type: none"> >> number of species of conifer and hardwood seedlings remained constant, >>shrub species doubled, >>forbs increased by 50%, >>grass species increased then leveled off at 11th year levels. <p>28 years post clearing, shrubs in the small openings were those that tolerate shade.</p> <p>The 2 larger opening sizes had significantly higher shrub density than the small openings.</p> <p>Forb and grass densities were not statistically different among opening sizes.</p> <p>Fern density was significantly different between the 9 and 27 meter openings.</p> <p>Southern aspect created greater density of shrubs, forbs, grasses and ferns.</p>

	<p>Shade tolerant conifers were able to establish 25 years post gap creation.</p> <p>The 9m diameter openings were too small for development of most vegetation. Roots of adjacent trees likely extend throughout the gap and remove resources. However, shade tolerant species found this gap size quite suitable.</p> <p>Using group selection cuttings, stands can be regenerated with a diversity of species while maintaining high forest cover, and help to form a spatially distinct age class.</p>
330	<p>Mellen-McClean, K. 2007. Pers. Comm.: Phone conversation on behalf of USDA Forest Service. July 19, 2007.</p> <p>1 - Very Relevant to Jackson WHMP</p> <p>Kim Mellen-McClean is the primary researcher responsible for integrating wildlife use data of dead wood into the DecAID advisory tool.</p> <p>The Forest Service often manages for "Natural Conditions" not wildlife species specifically.</p> <p>If the management goal is to manage for high quality wildlife habitat on all WHMP lands, then managing for dead wood at the 80% Tolerance Level across all acres would be appropriate (for the Large Tree vegetation condition that is applicable to Lake Chaplain, the prescription would be for 36.4 snags/acre \geq 10" dbh including 14/acre $>$ 20" dbh.)</p> <p>The information shown in the wildlife data (as opposed to the plot inventory data) came from areas around nests, so providing dead wood at these levels across all acreages may not be necessary.</p>
37	<p>Mellen, K., Ager, A. 2002. A coarse wood dynamics model for the western Cascades. In: Laudenslayer, W.F., Jr., Shea, P.J., Valentine, B., Weatherspoon, C.P., Lisle, T.E., eds. Proc. Symp. On the ecology and Management of dead wood in western forests. Gen. Tech Rep. PSW-GTR 181. USDA Forest Service: Pac. SW Res. Stn. p. 503-516.</p> <p>2 - Somewhat Relevant to Jackson WHMP</p> <p>Model used to project the recruitment, snag fall rate, height loss and decay rate of snags and down wood to predict future amounts of dead wood habitat creation. Snags either fall whole or in parts, creating down logs. Snags also decay from a hard to soft condition. Logs decay more slowly than snags, and eventually disappear into the forest floor as duff. The model can track remnant snags and logs (i.e. those existing on site at the beginning of the assessment time) and new snags and logs created from green trees.</p>
36	<p>Mellen, K., Marcot, B.G., Ohmann, J.L., Waddell, K.L., Willhite, E.A., Hostetler, B.B., Livingston, S.A., Ogden, K. 2002. DecAID: A decaying wood advisory model for Oregon and Washington. PSW GTR-181. USDA Forest Service. 527-533</p> <p>1 - Very Relevant to Jackson WHMP</p> <p>See #67</p>
67	<p>Mellen, K., Marcot, B.G., Ohmann, J.L., Waddell, K.L., Willhite, E.A., Livingston, S.A., Hostetler, B.B., Ogden, C., Dreisbach, T. 2006. DecAID - the decayed wood advisor for managing snags, partially dead trees, and down wood for biodiversity in forests of Washington and Oregon forests. Ver 2.0 US Forest Service, Pacific NW Region and Pacific NW Research Stn., Portland, OR.</p> <p>http://www.notes.fs.fed.us:81/pnw/DecAID/DecAID.nsf</p> <p>1 - Very Relevant to Jackson WHMP</p> <p>Computer program/management advisory tool.</p> <p>The DecAID database summarizes habitat associations of wildlife in terms of dead wood diameter and abundance. Can be used to determine either the species that would be provided</p>

for by retaining various densities and diameters of dead wood, or the levels of dead wood needed to provide habitat for species of interest.

DEFINITIONS:

Tolerance Level (TL) - an 80% tolerance level means that 80% of the population have a value for the given parameter that is between 0 and the value for the 80% TL. These are calculated based on 90% certainty levels. Example: an 80% TL of wildlife use of snag diameter means that 80% of all individuals observed uses snags less than or equal to some specified dbh, and 20% use snags greater than that dbh. The tolerance levels describe dead wood conditions across the total area within the vegetation condition.

Large Tree - Single Story - Closed Canopy - QMD $\geq 20"$; grass, shrub & seedling may occur in understory. Canopy cover is $>70\%$; tree size is 20-29" dbh; single canopy stratum.

Medium Tree - Single Story - Closed Canopy - QMD 10-19"; grass, shrub & seedling may occur in understory. Remnant trees can provide $<10\%$ canopy cover. Canopy cover is $>70\%$; tree size is 15-19" dbh; single canopy stratum.

FINDINGS - Snags & Cavity Nesters, Mike:

Selection for a given habitat attribute provides stronger evidence of a species' need than mere inventory data.

Uncarpeted Westside forests provide a reasonable estimate of historical conditions.

Advise against managing an entire landscape towards a particular tolerance level. Instead, distribution of habitat attribute should be guided by the distribution from unharvested plots. Areas should be managed within the complete range of dead wood values to provide for all species on the curve.

The value of live and dead hardwood trees and partially dead trees of all species, should not be overlooked.

If the objective is to manage for natural conditions rather than focusing on wildlife species, mimic distribution of unharvested acres (unharvested proportion of the landscape) in different snag density classes across the landscape. The percentages should be thought of as guidelines, since distributions largely reflect plot size and sample design. Balancing high, moderate and low densities of dead wood across a landscape may be desirable.

Species often use clumps of snag & dead wood. Numbers and sizes of clumps are not indicated by this data. Areas between clumps should not be devoid of snags; a mix of clumps and more widely distributed snags should occur at the stand level.

SPECIFIC RECOMMENDATIONS:

Clustered and scattered snags receive equal use for nesting and foraging.

Provide a variety of tree species, hardwoods and white pine are highly selected when available.

Particularly tall trees and snags (up to 110ft) are selected for, as roost trees by some bat species, esp. those that protrude above the canopy.

Retain all hollow trees snags and logs. Cedar and hemlock are more susceptible to hollowing.

Favor trees with fruiting fungal bodies, esp. of heart rot fungi, as well as forked tops, broken tops and brooms. These defective trees can substitute for some of the snags, counting

	<p>towards density & dbh requirements.</p> <p>For 80% TL, manage for 36.4 snags/ac \geq 10" dbh, with 14/ac $>$ 20" dbh. The complete range of diameters and densities should be managed for to provide for all species utilizing snags.</p> <p>Snags as large as 79" dbh should be provided for PWP roost trees. For all other species, snags $>$ 63" dbh should be provided.</p> <p>These data will provide a CONSERVATIVE APPROACH to snag habitat management.</p> <p>Wildlife use data and inventory data from unharvested plots both support managing snags at the 80% TL .</p> <p>Several studies indicate that even higher densities of snags are justified on at least some of the landscape, (46.9/ac $>$ 10" dbh and 14-20/ac $>$ 19.7" dbh).</p> <p>Snag densities such as these occur on 6-10% of the unharvested landscape.</p> <p>The 80% TL for DBH of snags used by wildlife (nesting, roosting and foraging) ranges from 33 to 79" dbh. Most nest and roost snags are greater than 47" dbh. All roost trees found were $>$ 43" dbh.</p> <p>Snags $>$ 39.4" dbh comprise about 7% of all snags measured, and occur on 54% of the unharvested lands in this vegetation condition.</p> <p>The 80% TL for DENSITY of snags used by wildlife ranges from 19-36/acre \geq 10" dbh, and 2-14/ac \geq 20" dbh. For unmanaged stands aged 80 to 195 years, the 80% TL provides 46.9/ac \geq 10" dbh and 13.9/ac \geq 19.7" dbh.</p> <p>LANDSCAPE DISTRIBUTION OF SNAGS IN NATURAL CONDITIONS: Data collected from unharvested stands -</p> <ul style="list-style-type: none"> ** 10% of the area has 36.4/ac \geq 10" dbh, this is similar to most of the data points at the 80% TL for WILDLIFE. ** 19% of the area has 14.2/ac \geq 19.7 " dbh, this is similar to most of the data points at the 80% TL for WILDLIFE. ** 18% of the area has 12.1 to 18.2/ac \geq 10" dbh, similar to the 50% TL. ** 40% of the area has 8.1/ac \geq 19.7" dbh, similar to the 50% TL. ** 81% of the area has 6.1/ac \geq 10" dbh, similar to the 30% TL. ** 37% of the area has 0 to 6.1/ac \geq 19.7" dbh, similar to the 30% TL. ** 4% of the area has no snags \geq 10" dbh. ** 5% of the area has no snag \geq 19.7" dbh. <p>TREE HEIGHT: Nest Tree Height ranged from 7' to 112'. Foraging Tree Height ranged from 49' to 75'. Den Tree Height for the N Flying Squirrel was 69'. Roost Tree Height ranged from 72' to 144', with bat species recording the highest roosts, typically taller than the surrounding canopy, and snag height was noted as the most important criteria for selection of bat roost trees.</p> <p>PWP selected for nest and roost trees that were \geq 90' tall and against those $<$ 57' tall. Increasing density of hard, tall snags led to an increase in abundance of hairy woodpeckers & red-breasted sapsuckers.</p> <p>Cavity Nesting Birds in the S. Wa Cascades preferred nesting in white pine snags.</p> <p>Based on tree availability, PWP on the Olympic Peninsula selected against hemlock and</p>
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	<p>selected for Silver fir as nest trees and selected for cedar as roost trees.</p> <p>Half of the nests and roost were found in decadent live trees, even though they were much more rare than snags.</p> <p>Densities of dead top live trees around PWP nest and roost sites was higher than at random sites.</p> <p>DISTRIBUTION OF SNAGS: **40% of the unharvested area and 30% of the total area supports > 18.2 snags/ac >= 10" dbh. ** 40% of the unharvested area and 29% of the total area supports > 8.1 snags/ac >= 19.7" dbh.</p> <p>Dwarf mistletoe is important for providing roosting and nesting structures for birds and small mammals. Hemlock is most susceptible, and therefore the most important for wildlife habitat. 14% of unharvested and 12% of harvested plots have some level of infection by mistletoe.</p> <p>Removing woody structure can have short-term benefits to planted seedling growth but longer-term adverse effects on overall forest productivity.</p>
20	<p>Mellen, T.K. 1987. Home Range and Habitat Use of Pileated Woodpeckers, Western Oregon. La Grande, OR. Oregon State University. Master of Science Dissertation. 96p. 1 - Very Relevant to Jackson WHMP</p> <p>Home range size averaged 490 ha for individual birds, ranges of pairs were larger. This is larger than that reported from other studies. Pileated WP preferred forest habitat classes older than 40 years, as well as riparian forests for foraging and other diurnal activities. Nesting and roosting occurred in forest stands older than 70 years of age. "Preferred" habitat is not necessarily required. Only 43% of birds in this study had old growth in their home range. Old growth was not selected for in disproportion to its availability. Nests and roosts were located in forest habitats older than 70 years. This type of habitat made up 44% (200 ha) of the average home range. Average density of PWP is 1 bird/200 ha.</p> <p>"Caution should be exercised in using the PWP as an 'indicator species' for snag dependent species; meeting snag density requirements for this species may not meet snag density requirements of other primary cavity excavators which occur at higher densities."</p> <p>Management goals should provide at least the mean number of snags required, rather than the minimum. Mean dbh of nest trees = 68.9cm, and roost trees = 118.2cm. Typical nest or roost snag had a broken top and retained most of the bark. Nest and roost snags typically had few limbs, as opposed to live nest and roost trees, where numerous live limbs were present. Snags averaged 41/ha at nest sites and 40/ha at roost sites. Canopy cover averaged 68% at nest sites and 74% at roost sites. Shrub cover averaged 72% at nest sites and 74% at roost sites. W OR is the only area where PWP have been found to nest extensively in Douglas fir. Suggestions have been made that Douglas fir are not used for nesting because the sapwood decays more rapidly than the heartwood. Typical nest site has high basal area, high densities of trees and snags and high densities of large trees and snags.</p> <p>Recommends providing snags close to the mean of 70cm dbh.</p>
92	<p>Mellen, T.K., E.C. Meslow and R.W. Mannan. 1992. Summertime Home Range and Habitat Use of Pileated Woodpeckers in Western Oregon. J. Wildl. Manage. 56:96-103. 1 - Very Relevant to Jackson WHMP</p> <p>Radio telemetry was used to track PWP over a 4 year period to determine home range and habitat use preferences in the Oregon Coast Range. Home range size for adult birds after</p>

	<p>young had fledged average 478ha (range 267 - 1,056 ha). This is larger than other studies have reported, but is one of the only at the time to have used radio telemetry. Nesting and roosting occurred only in stands older than 70 years, but they are known to forage in younger stands. Old growth habitat was selected for in proportions moderately greater than its availability (<1.5 times availability). Forests older than 70 years averaged 47% of home ranges (255ha).</p> <p>Nest trees (n = 18) average 71 cm dbh (range 40 - 138 cm) Roost trees (n = 15) averaged 112 cm (range 40 - 208cm)</p>
170	<p>Messere, M. and P.K. Ducey. 1998. Forest Floor Distribution of Northern Redback Salamanders, <i>Plethodon cinereus</i>, in Relation to Canopy Gaps: first year following selective logging. <i>For. Ecol and Manage.</i> 107:319-324.</p> <p>Study of amphibians within gaps in northern hardwood forests, focusing on Northern Redback Salamanders.</p>
179	<p>Morrison, M.L. and M.G. Raphael. 1993. Modeling the Dynamics of Snags. <i>Ecol. Appl.</i> 3:322-330.</p> <p>3 - Not Relevant to Jackson WHMP</p> <p>Study conducted in Sierra Nevada mountains in California</p>
68	<p>Morrison, M.L., Dedon, M.F., Raphael, M.G., Yoder-Williams, M.P. 1986. Snag requirements of cavity-nesting birds; are USDA Forest Service guidelines being met? <i>West. J. Appl. For.</i> 1:38-40.</p> <p>1 - Very Relevant to Jackson WHMP</p> <p>Relevant, but written in 1986, and already a reference for the WHMP.</p>
140	<p>Nelson, S.K. 1988. Habitat Use and Densities of Cavity Nesting Birds in the Oregon Coast Ranges. Corvallis, OR, USA. Oregon State Univ. Master's Thesis. 1988; 157p.</p> <p>1 - Very Relevant to Jackson WHMP</p> <p>no PUD copy - available from OSU library.</p> <p>Abundance of many cavity nesting species, including Pileated WP (PWP) and red-breasted sapsuckers (RBS) increased with stand age and were positively associated with density of large conifers.</p> <p>Abundance of PWP was positively correlated with abundance of large (>50cm) class II & III snags, and has been reported by others to reach maximum in mature or old-growth forests.</p> <p>A negative association was found between cavity-nester abundance and the abundance of small snags and trees, common to young forests.</p> <p>Small snags (<50cm) were found to provide inadequate nest sites for flickers</p> <p>Most (70%) nests were located in class II & III snags with notes signs of decay, particularly conks of <i>Fomes</i> and exposed heartwood.</p> <p>Secondary cavity-nesters used class V snags more often than did primary excavators.</p> <p>Hairy WP and Flickers were found to avoid class V snags entirely, and nested predominantly in trees with not evidence of decay.</p> <p>** Mean nest tree diameter was 94cm.</p> <p>PWP only nested in class II & III snags.</p> <p>Of all primary and secondary cavity nesters, 70% (172 of 244 nests) nested in class II & III snags.</p>

	<p>Nest trees were taller, larger dbh and had more limbs than available snags.</p> <p>For nest trees, 86% of snags had broken tops, and 52% of live trees had broken tops.</p> <p>Decay class II & III snags were selected for, and classes I, IV & V were avoided, based on availability.</p> <p>*** 73% of nests were found in snags ≥ 50cm, with snags 50-99cm being used 2x their availability, and snags >99cm being used more than 4x their availability.</p> <p>*** Snags 21-30m tall were used 2.5x availability; 31-40m used 5.5x availability, and >40m used 9x availability.</p> <p>53% of all nest trees were decay class II or III and ≥ 50cm (the next highest use was of medium sized snags (20-49cm dbh) in classes II & III, at 18%). Class II & III snags were used in greater amounts than available.</p> <p>Mean nest tree height = 31m.</p> <p>Snags 50-99 cm & >99cm were used significantly more than available by PWP, hairy, flicker and sapsucker for nest trees.</p> <p>Snags 21-30m, 31-40m & >40m were all used in significantly greater proportions than available.</p> <p>Woodpecker species never nested simultaneously in the same snag.</p> <p>Ten snags were reused by the same species in successive years, but the same cavity was never utilized. These trees were typically (81%) in old-growth stands, in large (≥ 50 cm dbh), tall (>17m) hard snags (81% in classes I, II or III).</p> <p>Snag height and diameter were found to be the most important determinants in which snags were used for nesting, both being greater than available.</p> <p>*** Use of tall (>40m), large (≥ 50cm) snags exceeded availability in all stand types.</p> <p>36% of live nest trees in mature forests (> 80 y.o..) were in live big-leaf maple, the remainder being in Douglas-fir.</p> <p>Cavity-nesting birds were found to nest in snag patches, containing high densities of medium and large snags, and dense midstory and understory cover.</p> <p>Cavity-nesters preferred to nest in areas with $>48\%$ midstory and understory cover, 59% of nests occurred in area with these high cover levels.</p> <p>*** Nest sites were more often found in areas with ≥ 11 medium or large (20-49 cm dbh or 50cm dbh +) snags/ha.</p> <p>*** Cavity nesters avoided sites with fewer than 1 medium of large snag/ha.</p> <p>*** Presence of supercanopy trees was significantly higher (9x) at nest sites than random sites.</p> <p>Across all stand types, birds preferred to nest in large (≥ 50 cm dbh; ≥ 21 m tall), hard snags with numerous limbs. Subtle differences occurred among species in nest-tree preference for tree diameter, cavity height and decay condition.</p>
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	<p>Douglas fir sapwood decays more rapidly than heartwood, so in large snags, this pattern may aid in cavity excavation and longevity, since it decays more slowly than many other species.</p> <p>Hemlock decays rapidly and may not meet birds' preferences for hard snags.</p> <p>70% of nests were found in snags from decay class II & III; exceeding availability in all stand types.</p> <p>The largest and tallest snags available were chosen for nest trees, with nests placed at the highest possible diameter.</p> <p>Large (>50cm dbh) Douglas-fir snags have been reported (Cline 1978) to last an average of 125 years in the PNW and up to 200 years before becoming a rotten stump. Snags <50 cm dbh are usually well decayed by 60 years (Cline 1980).</p> <p>Midstory and understory cover were important selection criteria in all stand types. These are often caused by natural canopy gaps and help to create an uneven vertical profile. Shrub cover has been found to be an important characteristic to cavity-nesting birds.</p> <p>Providing snag patches in managed forest would mimic the natural distribution of snags.</p> <p>Management for snags ≥ 94cm dbh will provide for the greatest diversity of cavity-nesting birds.</p> <p>Managing for minimum diameters will likely provide sub-optimal habitat and may have negative effects on reproductive success.</p> <p>This study found that mean snag diameters for all species and minimum sizes for flickers exceeded the minimums suggested by Nietro et al. 1985.</p> <p>Managing for mean diameters is supported by this study.</p> <p>Mean snag height for all cavity nesters was 31m.</p> <p>Only 27% of all nests were in snags <50 cm.</p> <p>*** Due to limited statistical differences found between nest-tree characteristics of all cavity-nesting species, managing for the needs of primary cavity nesters will also meet the needs of other snag dependent species.</p> <p>Cavity-nesters used snag patches associated with high midstory and understory cover, and a mean of 19 large snags/ha.</p> <p>*** Several species are highly unlikely to use snags in clearcuts; red-breasted nuthatch, brown creeper and PWP avoid nesting in clearcuts. Only management for mature (80-200 y.o..) and old growth forests or large sang islands will provide for the habitat needs of these interior forest species.</p> <p>Habitat islands within managed forests should also meet the needs of habitat generalists such as hairy wp, flickers and chestnut backed chickadees, although they have been found to nest in clearcuts.</p> <p>Red-breasted sapsuckers prefer dense midstory and understory cover, so leaving or creating large snags (>94cm) in dispersed patches in mature forests or in riparian strips may provide the necessary habitat.</p>
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	<p>RECOMMENDATIONS:</p> <ul style="list-style-type: none"> ** Douglas fir snags meet the needs of most cavity nesters. ** Preserve existing hard snags in classes II & III and retaining green trees for replacement. ** Manage for mean sizes of trees; large snags (>94 cm, >31m tall) should be maintained and created in all intensively managed and unmanaged forests. ** Stands larger than 40 ha will be required to create forest interior habitat and reduce edge effect. These areas should be virtually free of forest management activities. ** In intensively managed forests, extending rotation age to >80 years will allow for creating or retaining larger snags which are most preferred. ** Modified shelter wood cuts should be used in even-aged management stands. Retain 12-15 large (>= 50 cm) live trees/ha. ** Snag habitat islands should include >19 large snags/ha (mean # from this study) and large live replacement trees with intact mid- and understory canopy. These areas should also include hardwoods, especially big-leaf maple. Each clearcut should have these habitat islands, to supply adequate distribution across the landscape.
167	<p>North, M.P., J.F. Franklin, A.B. Carey, E.D. Forsman & T. Hamer. 1999. Forest Stand Structure of the Northern Spotted Owl's Foraging Habitat. <i>For. Sci.</i> 45:520-527.</p> <p>1 - Very Relevant to Jackson WHMP</p> <p>In the CART analysis a snag volume greater than 142.1m³/ha was correlated with an increase in foraging use from low to medium and high in these study areas.</p> <p>** 70% of the snag volume was derived from large snags (dbh >50 cm) rather than the small but numerous suppressed and intermediate dead trees.</p> <p>Snag sizes were variable on sample plots, but medium and high use areas often had large rot-resistant snags (cedar or Douglas-fir) resulting from the site's past disturbance.</p> <p>The size of large snags on medium and high foraging use areas averaged 86 cm dbh (SD 15.4) and 24 m tall (SD 14.3) with a mean density of 15/ha (SD 4.6)</p>
72	<p>Ohmann, J.L., McComb, W.C., Zumrawi, A.A. 1994. Snag abundance for primary cavity-nesting birds on nonfederal forest lands in Oregon and Washington. <i>Wildl. Soc. Bull</i> 22:607-620.</p> <p>1 - Very Relevant to Jackson WHMP</p> <p>Snag abundance patterns were assessed based on plant community type and stand conditions on both managed and natural forests on nonfederal lands. Data should be considered averages for 14 million acres across these lands. Densities and snag characteristics were characterized for a wide range of stand conditions. Models of the snag-bird relationship were used in an attempt to predict the role of non-federal lands in providing habitat for primary cavity-nesters. Implications of forest management in the Northwest are also discussed. Mean ages of closed sapling-pole-sawtimber, open saw and large saw found on these lands are given. Detailed tables break down snags by diameter and decay class, and show mean density of snags for each of the above listed forest canopy types in coniferous forests as well as conifer-hardwood mixed forests. Based on the mean density & sizes of snags, old growth forest was the only cover type predicted to support 100% of the Maximum Potential Population of all species simultaneously.</p>
64	<p>Ohmann, J.L., Waddell, K.L.. 2002. Regional patterns of dead wood in forested habitats of Oregon and Washington. In: Laudenslayer, W.F. et al. eds. <i>Proceedings of the Symposium on the Ecology and Management of Dead Wood in Western Forests</i>. US Forest Service PSW-GTR-181. pp. 535-560.</p> <p>1 - Very Relevant to Jackson WHMP</p> <p>Mike:</p> <p>Analysis of dead wood (snags & CWD) across 20 million hectares (over 16,000 field plots) of Federal and non federal lands in OR & WA, divided by the Cascade Crest.</p> <p>Dead wood abundance increased with successional age.</p>

	<p>SNAGS: Mean density of snags ≥ 25.4 cm dbh, all decay classes, ≥ 2 m tall, by forest type and successional stage:</p> <p>West side conifer-hardwood – Early succession = 5.3/ha Middle succession = 12.3/ha Late succession = 14.6/ha All stages = 10.2/ha</p> <p>West side Conifer Early succession = 5.2/ha Middle succession = 21.4/ha Late succession = 34.0/ha All stages = 16.1/ha</p> <p>West side conifer-hardwood forests had 2nd most numerous population of large snags (behind montane mixed-conifer forest, due to slow deterioration of snags)</p> <p>Mean density of LARGE snags ≥ 50.0 cm dbh, all decay classes, ≥ 2 m tall, by forest type and successional stage:</p> <p>West side conifer-hardwood – Early succession = 2.1/ha Middle succession = 4.2/ha Late succession = 7.8/ha All stages = 3.7/ha</p> <p>West side Conifer Early succession = 2.1/ha Middle succession = 7.5/ha Late succession = 15.6/ha All stages = 6.4/ha</p> <p>Bernice, much of this chapter also deals with CWD</p>
325	<p>O'Neil, T.A., Johnson, D.H., Barrett, C., Trevithick, M., Bettinger, K.A., Kiilsgard, C., Vander heyden, M., Greda, E.A., Stinson, D., Marcot, B.G., Doran, P.J., Tank, S., Wunder, L. 2001. Matrixes for wildlife-habitat relationship in Oregon and Washington. In Johnson, D.H., O'Neil, T.A., dirs. Wildlife-habitat relationships in Oregon and Washington. Corvallis, OR: Oregon State Univ. Press.</p> <p>2 - Somewhat Relevant to Jackson WHMP</p> <p>Digital tables with compiled information on (1) wildlife-habitat types, e.g. forest type; (2) structural conditions, e.g. forest structure, grassland, wetland, etc.; (3) habitat elements, e.g. snags, CWD; (4) key ecological functions, (5) life history, (6) salmon-wildlife relationship, and (7) management activity links.</p>
51	<p>Parks, C.A., Bull, E.L., Filip, G.M. 1994. Creating wildlife trees in managed forests using decay fungi. Poster presented at Symposium, Partnerships for Sustainable Forest Ecosystem Management. Guadalajara, Mexico, Oct. 16-22, 1994.</p> <p>2 - Somewhat Relevant to Jackson WHMP</p>
238	<p>Parks, C.G., C.M. Raley, K.B. Aubry and R. L. Gilbertson. 1997. Wood Decay Associated with Pileated Woodpecker Roosts in Western Redcedar. Plant Disease 81:551.</p> <p>1 - Very Relevant to Jackson WHMP</p> <p>Short abstract:</p> <p>Large cedar that contain heart rot before they die persist longer and provide roost sites for a far longer time than other species.</p>
291	<p>Parks, C.G., E.L. Bull and G.M. Filip 1995. Using Artificially Inoculated Decay Fungi to Create Wildlife Habitat In: Bradford, P., T. Manning and B. l'Anson eds. Wildlife Tree/ Stand-Level Biodiversity Workshop Proceedings. Victoria, B.C. October 1995. 87-90.</p> <p>2 - Somewhat Relevant to Jackson WHMP</p>

	<p>Study was conducted in NE OR on western larch.</p> <p>Six years after artificial inoculation, 8 of 10 trees are being used by cavity nesters. All trees remain alive with viable crowns.</p> <p>Little chance of spread to other trees from inoculation procedures.</p>
44	<p>Parks, C.G., Raley, C.M., Aubry, K.B. (and others). 1997. Wood decay associated with pileated woodpecker roosts in western redcedar. Plant Disease 81:551.</p> <p>1 - Very Relevant to Jackson WHMP</p> <p>Large cedar trees containing heart rot before they die may be especially important to PWP because these trees provide potential roost sites and will persist far longer than other tree species; they may even last for centuries.</p>
242	<p>Parks, C. G. and D. C. Shaw. 1996. Death and Decay: A Vital Part of Living Canopies. Northwest Sci. 70: 46-53.</p> <p>3 - Not Relevant to Jackson WHMP</p> <p>Background info on dead and decaying trees in forest environments; no specific info or recommendations.</p>
111	<p>Pers. Comm: Alaback, P. 2007. E-mail on behalf of University of Montana. March 22, 2007.</p> <p>1 - Very Relevant to Jackson WHMP</p> <p>03/22/07 Huckleberry revert to a juvenile-like form with low growing, prostrate limbs and small evergreen leaves following canopy closure, and can persist as long as they are in deep shade. Following a disturbance, they will change growth form to an upright deciduous shrub. Red huckleberry keeps some of these evergreen shoots at the base and is most prone to this condition, but he has noted it in most NW huckleberry species.</p> <p>05/01/07 Elliptical shaped gaps may appear more natural and also be less prone to windthrow. Regeneration of hemlock can be reduced by opening the canopy enough to encourage shrub growth but not enough to encourage mass influx of hemlock seedlings. Suggests using a fisheye lens on digital camera to calculate the sun movement.</p> <p>5/25/07 Amount of light into forest under a gap varies depending on latitude and cloudiness. Hemlock invasion occurred on sites with greater than 4 or 5% light input. Old-growth is typically 0-5%. He suggests trying a couple different sizes of gaps aiming for 5, 10 and 15% light input to study the differences.</p>
294	<p>Pers. Comm: Buursma, Ed. 2007. Phone conversation on behalf of Mt Hood National Forests, Clackamas Ranger District. May 16, 2007.</p> <p>1 - Very Relevant to Jackson WHMP</p> <p>In riparian reserve areas adjacent to harvest units, 10 trees/acre were topped, 10/ac girdled, and some felled to thin out dense second growth.</p> <p>About 3 out of every 10 snags are placed in clumps.</p> <p>Have been inoculating for a few years, but have no results yet.</p> <p>Have been topping snags for about 20 years.</p>
297	<p>Plum Creek Timber Company, Inc. 2000. Central Cascades Habitat Conservation Plan.</p> <p>1 - Very Relevant to Jackson WHMP</p> <p>During all operations, including even-aged harvests, the Environmental Principles will result in post-harvest conditions that exceed State Forest Practices Rules and Regulations. This will occur in several ways:</p> <p>1. Where snags are lacking, additional green recruitment trees will be left instead.</p>

	<p>2. The number of snags left will exceed State Forest Practices Rules and Regulations. Although not every harvest-unit will have sufficient snags prior to harvest to meet these objectives, when considered in total, Plum Creek's even-aged harvest-units will average three snags retained per acre harvested.</p> <p>3. Larger snags will be given priority for retention, and Plum Creek will leave three green recruitment trees that are either dominants or codominants.</p> <p>4. Snags and recruitment trees will be either clumped or scattered across harvest-units depending on operational feasibility. Clumping and scattering offer differing benefits to different species. Over time and the landscape, the use of both distribution strategies will result in benefits to many species. A common strategy may be to clump leave trees along intermittent streams or adjacent to existing riparian protection areas. Under unusual situations, leave trees for a harvest-unit may be left in adjacent riparian protection areas after consultation with the Services. These leave trees would be over and above the number required by the combination of the Riparian Management Strategy and watershed analysis.</p>
295	<p>Plumage, Jesse. 2007. Phone conversation on behalf of Mt Baker Snoqualmie National Forest, Darrington Ranger District. May 16, 2007.</p> <p>1 - Very Relevant to Jackson WHMP</p> <p>Have not conducted any snag creation for some years, were not sure if it was providing the desired results, BUT also had no money to monitor them.</p> <p>Only conducting commercial thinnings now, and snags aren't required.</p> <p>15% of the area is left as residual green trees in clearcuts under the NW Forest Plan.</p>
14	<p>Public Utility District No. 1 of Snohomish County and City of Everett, Washington. 1988. Wildlife Habitat Management Plan, Henry M. Jackson Hydroelectric Project, 3 Vol., Paging various.</p> <p>1 - Very Relevant to Jackson WHMP</p>
158	<p>Raley, C.M., and K.B. Aubry. 2006. Foraging Ecology of Pileated Woodpeckers in Coastal Forests of Washington. JWM 70:1266-1275.</p> <p>1 - Very Relevant to Jackson WHMP</p> <p>In wet coastal forests, dead trees (snags) and live trees with dead or broken tops (decadent trees) are commonly used for nesting by pileated woodpeckers (Aubry and Raley 2002a, Hartwig et al. 2004), whereas in drier inland forests, live trees are used much less frequently (Bull 1987, Bull et al. 1992b, McClelland and McClelland 1999).</p> <p>Did not search live trees with live tops for recent excavations because they were rarely used by pileated woodpeckers for foraging (9 of 412 structures used by radiomarked birds were live, intact trees; C. Raley and K. Aubry, unpublished data).</p> <p>The relative abundance of carpenter ants differed substantially between precanopy and closed-canopy habitat conditions; capture rates along logs and near cut stumps in pre-canopy stands were >10 times greater than capture rates in the same microsites in closed-canopy stands (Fig 2).</p> <p>Virtually all structures used by pileated woodpeckers for foraging were trees (93% snags and 2% decadent); 3% were cut stumps and 2% logs.</p>

Results of logistic regression analysis showed that pileated woodpeckers selected relatively tall, large-diameter snags in early to moderate stages of decay for foraging

Fifty-seven percent of trees with recent foraging excavations were ≥ 81 cm diameter at breast height (median = 85 cm), 70% were ≥ 7.5 m tall (median = 15 m), and 52% had $\geq 75\%$ intact bark (median = 80%;). In contrast, trees without recent foraging excavations were smaller and more decayed; 76% were <81 cm diameter at breast height (median = 52 cm), 67% were <7.5 m tall (median = 5 m), and 58% had $<75\%$ intact bark (median = 40%;). Based on median values of diameter at breast height and height, the estimated volume of wood in trees used for foraging was 7 times greater than for trees that were not used.

pileated woodpeckers selected sites for foraging that had greater densities of large (>51 cm dbh and ≥ 7.5 m tall) snags. Most (70%) plots with recent pileated woodpecker foraging activity had ≥ 3 large snags (median = 4). In contrast, plots with no recent foraging activity typically had <3 large snags (63%; median = 2).

Despite the abundance of logs in coastal forests (Table 3), pileated woodpeckers rarely foraged on them.

In the Coast Range of Oregon, $>50\%$ canopy cover greatly reduced the likelihood that carpenter ants (*C. modoc*) could successfully establish and maintain their nests (Nielsen 1986). This species was only found in forest clearings where there was enough solar radiation to warm the forest floor and associated coarse woody debris. Our results provide additional evidence that logs in coastal forests are too cool and wet to support abundant populations of carpenter ants.

Snags used by pileated woodpeckers for foraging were larger in diameter and height and less decayed than those that were not used. Carpenter ant colonies are often large (Hansen and Antonelli 2005) and need correspondingly large structures to accommodate colony growth. Additionally, dampwood termite colonies nest and feed entirely within the host structure (Rosengaus et al. 2003). Thus, relatively large snags would provide greater volumes of wood and better habitat conditions for these arthropods over a longer period of time than small snags.

Our results support our hypothesis that selection of foraging sites by pileated woodpeckers is influenced by the abundance of potential foraging structures.

Despite the presence of potential foraging structures and large numbers of carpenter ants in open precanopy habitat conditions, they were rarely used by pileated woodpeckers for foraging. Due to threat of predation, open habitats in coastal forests may provide inadequate escape cover for pileated woodpeckers.

Current Forest Plan manages for nesting habitat for PWP, not for feeding or roosting. Our results indicate that maintaining populations of pileated woodpeckers in coastal forests may require a more comprehensive management strategy that also includes provisions for foraging (this study) and roosting (Aubry and Raley 2002a) habitat.

	<p>To maintain or improve foraging habitat for pileated woodpeckers, we suggest that managers emphasize the retention of large (>51 cm dbh and >/_7.5 m tall), relatively hard snags. Additionally, we suggest that retaining patches of large snags (rather than dispersed structures) in closed-canopy habitat conditions would provide optimal foraging habitat for pileated woodpeckers.</p> <p>SEE SUPPORTING DOCS FOR DATA TABLE SUMMARY.</p>
247	<p>Risenhoover, K.L., Murden, S.B. 2006. Managing for wildlife in intensively managed forests: a landowner perspective. In Harrington, T.B., G.E. Nicholas, tech. eds. Managing for wildlife habitat in west-side production forests. Gen. Tech. Rep. PNW-GTR-695. Portland, OR:USDA Forest Service, Pac. NW Res. Stn. Pp. 107-116.</p> <p>2 - Somewhat Relevant to Jackson WHMP</p> <p>Observations and studies from Port Blakely foresters: Emphasized retention of legacy features: stumps, green trees, wildlife(defective) trees, logs and snags in even-age managed forests because within-stand structural diversity is low.</p> <p>Woody debris has a mulching effect. Benefits include moisture retention and heat abatement for wildlife--results of a study forthcoming. Reforestation isn't greatly impeded by logging slash; anecdotal evidence that there is less browse on tree seedlings.</p> <p>Understory conifers are retained to increase diversity</p> <p>RMZs over time will account for a large % of the landscape. Will develop into mature age classes, provide connectivity for wildlife, and source of large snags</p> <p>Ecologically sensitive sites: cliffs, caves, rock outcrops, seeps and spring.</p> <p>Don't replant natural meadows.</p> <p>Misgivings about created snags: decay processes not the same as in natural snags. More Weyerhaeuser studies coming out soon. Old Weyco studies compared snag longevity from different methods. Drought-, lightning- and wind-killed snags lasted the longest. Snags killed by herbicide and laminated root-rot didn't last as long.</p>
70	<p>Rose, C.L., Marcot, B.G., Mellen, T.K. and others. 2001. Decaying wood in Pacific Northwest forest: concepts and tools for habitat management. In: Johnson, D.H., O'Neil, T.A. eds. Wildlife-habitat relationships in Oregon and Washington. Corvallis, OR: Oregon State University Press. Chapter 24.</p> <p>1 - Very Relevant to Jackson WHMP</p> <p>Mike's notes:</p> <p>Since the publication of Thomas et al. 369 and Brown, 48 new research has indicated that more snags and large down wood are needed to provide for the needs of fish, wildlife, and other ecosystem functions than was previously recommended by forest management guidelines in Washington and Oregon. For example, the density of cavity trees selected and used by cavity-nesters is higher than provided for in current management guidelines. 53, 102 Reductions</p> <p>Habitat suitability for cavity-users is influenced by the size (diameter and height), abundance, density, distribution, species, and decay characteristics of snags. 307 In addition, the structural condition of surrounding vegetation determines foraging opportunities. 402</p> <p>Total snag densities were greatest at higher elevations: 15.1/ac (37.2/ha) in montane mixed-conifer forest and 14.6/ac (36.0/ha) in subalpine parks (Table 1).</p>

Snags were least dense in the drier wildlife habitat types on the eastside: 0.3/ac (0.8/ha) in western juniper woodland and 2.0/ac (5.0/ha) in eastside ponderosa pine (Table 1). Large snags were most abundant in montane mixed-conifer forest (3.8/ac; 9.6/ha) and in westside conifer-hardwood forest (2.2/ac; 5.5/ha), and least abundant in western juniper woodland (0.1/ac; 0.2/ha) and ponderosa pine (0.4/ac; 1.0/ha) (Table 1).

A large proportion of the plots contained no snags or down wood, and a very small proportion of the plots contained extremely large accumulations of dead wood. Mean values for these skewed distributions must be interpreted with caution. The distribution of snags for the conifer alliance of westside conifer-hardwood forest (Figure 11) illustrate this pattern. In this wildlife habitat type, 39 percent of the area sampled had no snags.

Several major lessons have been learned in the period 1979-1999 that have tested critical assumptions of these earlier management advisory models:

- . Calculations of numbers of snags required by woodpeckers based on assessing their biological potential. (that is, summing numbers of snags used per pair, accounting for unused snags, and extrapolating snag numbers based on population density) is a flawed technique. Empirical studies are suggesting that snag numbers in areas used and selected by some wildlife species are far higher than those calculated by this technique.²²⁶
- . Setting a goal of 40% of habitat capability for primary excavators, mainly woodpeckers,³⁶⁹ is likely to be insufficient for maintaining viable populations.
- . Numbers and sizes (dbh) of snags used and selected by secondary cavity-nesters often exceed those of primary cavity excavators.
- . Clumping of snags and down wood may be a natural pattern, and clumps may be selected by some species, so that providing only even distributions may be insufficient to meet all species needs.
- . Other forms of decaying wood, including hollow trees, natural tree cavities, peeling bark, and dead parts of live trees, as well as fungi and mistletoe associated with wood decay, all provide resources for wildlife, and should be considered along with snags and down wood in management guidelines.

In addition, it may be both biologically and operationally beneficial to create and preserve snags within patches of uncut trees, rather than to distribute them uniformly across stands.

Trees topped above two branch whorls survive and develop new tops. Continued diameter growth in these trees provide higher values as wildlife snags.

	<p>Large crooks formed in these trees also provide platform nest sites and create future breaking points to form a tall snag. The greater longevity of these live-topped trees should reduce the need to cause intentional mortality in leave trees in the future.</p> <p>Topped trees rapidly develop cavities throughout the bole. Live-topped trees develop cavities ten years after topping, with cavities forming first near the upper bole. The creation of live trees with cavity habitat is highly desirable, as it allows cavity habitat to be maintained over longer periods.</p> <p>Big-leaf maple has relatively high survival and provides a high density of cavity sites.</p> <p>Notes on CWD:</p> <p>The volume of total and large down wood generally increases with forest development: large successional stages contained the largest concentration of both total and large down wood, although some young stands may inherit CWD and live trees from preceding stands. In westside forests, the volume of total and large down wood in the late stage usually was significantly different from the early and mid stages, but early and mid stages were usually not significantly different from one another. CWD has a longer lag time in forests than snags and is less likely to be disturbed by management activities.</p> <p>Estimates of mean total WD (>4.9 in large end, >6.6 ft long) volume in 3 successional stages of westside conifer-hardwood forest ranged from 2,169 to 3,233.8 cu ft/ac. Large WD (>19.7 in large end, >6.6 ft long) ranged from 1,408 to 2,469 cu ft/ac.</p> <p>Management tools and opportunities</p> <p>Retain large snags, large decadent trees, and logs from previous rotation. To reduce safety and operational hazards, cluster snags in patches rather than wide dispersal, and create snags from green trees after harvest.</p> <p>Green tree retention (10-40%) of living trees, including dominants, through next rotation. Green tree retention on a harvest cycle of 120 yrs proposed as a method to provide habitat for late successional spp in only 40-50 yrs. The DEMO program offers information on wildlife and vegetation response to green tree retention.</p> <p>Variable density thinning. Also, aggregated or "patch" retention of small forest patches instead of dispersed retention, is suggested.</p> <p>Thinning and long rotations promote stand development and, thus, larger trees available for dead wood creation.</p>
184	<p>Schlicht, R. and Y. Iwasa. 2004. Forest Gap Dynamics and the Ising Model. J. Theor. Biol. 230:65-75.</p> <p>3 - Not Relevant to Jackson WHMP Study was conducted in Japan</p>
112	<p>Schreiber, B. And D.S. deCalesta. The Relationship Between Cavity-Nesting Birds and Snags on Clearcuts in Western Oregon. For. Ecol. And Manage. 50:299-316.</p> <p>1 - Very Relevant to Jackson WHMP Snag Diameter: Cavity Nesting Birds (CNB) utilized snags according to their availability,</p>

	<p>except that they avoided snags less than 28 cm, and selected for snags from 78-102 cm DBH. Many large diameter snags were short, decayed remnants and may have lacked some of the beneficial aspects of large-diameter snags suggested in other studies.</p> <p>Snag Height: Snags in all height classes greater than 6.4m were selected for</p> <p>Decay Class: Decay class 3 snags were selected for, and decay classes 1, 2 & 5 were avoided.</p> <p>Bark Cover: CNB as a group selected snags of significantly higher percent bark cover than available.</p> <p>A significant correlation was noted between CNB and snag density.</p> <p>***Recommend retaining or creating snags of the largest diameters possible, since they will stand longer.</p> <p>Snags that had been dead for 20-50 years were selected, and snags with either newer, harder wood, or snags with advanced deterioration were avoided.</p> <p>*** Recommend providing snags with a full range of bark cover, since high bark cover was preferred.</p> <p>When snag density was less than 10/ha, CNB density was 0.3 birds/ha or less, and was likely constrained by lack of nest sites.</p> <p>***Higher species richness and densities might accrue from snag densities > 25/ha.</p> <p>***Selecting snags with the most likelihood of CNB use may reduce the overall number required: a more realistic number of snags to leave on clearcuts might be the number found with nests (14/ha) is only snags of dbh, height, hardness and bark cover selected by CNB are retained.</p> <p>Recommend leaving 14 snags/ha., between 28 and 128+ cm dbh, 6.4 to 25m tall, 10-40%+ bark cover, most in decay stages 3 & 4.</p>
143	<p>Specifications for meeting habitat requirements for pileated woodpecker and pine marten. 1990. Mt. Baker-Snoqualmie National Forest. Final EIS - Land and Resource Management Plan, Appendix H. Seattle, WA:USDA Forest Service, PNW Region, p. H-16 to H-23.</p> <p>2 - Somewhat Relevant to Jackson WHMP</p> <p>May be out of date information, but see tables in Supportive Link</p>
107	<p>Spies, T.A. and J.F. Franklin. Gap Characteristics and Vegetation Response in Coniferous Forests of the PNW. Ecology 70:543-545.</p> <p>1 - Very Relevant to Jackson WHMP</p> <p>Douglas fir is unlikely to reach the canopy in gaps of less than 700 to 1000 sq meters in the W. Hemlock Zone.</p> <p>Light penetration under the forest canopy is less than 5% of full sunlight.</p>
135	<p>Spies, T.A., Franklin, J.F. 1988. Old growth and forest dynamics in the douglas-fir region of western Oregon and Washington. Nat. Areas. J. 8(3):190-201.</p> <p>2 - Somewhat Relevant to Jackson WHMP</p> <p>Provides interim definitions for old growth in the Douglas-fir and mixed conifer region of Washington, Oregon and northern California, based on minimal numbers and sizes of large live trees, canopy structure, snags and logs. For Douglas-fir on western hemlock sites (western</p>

	<p>hemloc, Pacific silver fir) stand characteristics are as follows:</p> <p>live trees: Two or more species with wide range of ages and sizes. Douglas-fir >8 per acre of trees >32 inches or >200 years old. Tolerant associates (western hemloc, western redcedar, Pacific silver fir, grand fir, or big-leaf maple) >12 per acre of trees >16 inches</p> <p>canopy: deep multi-layered canopy</p> <p>snags: conifer snags >7 per acre that are >20 inches in diameter and >15 ft. tall</p> <p>logs: Logs >15 tons per acre including 4 pieces per acre >24 inches in diameter and >50 ft. long</p>
103	<p>Spies, T.A., J. F. Franklin and M. Klopsch. 1990. Canopy Gaps in Douglas-fir Forests of the Cascade Mountains. <i>Can. J. For. Res.</i> 20:649-658.</p> <p>1 - Very Relevant to Jackson WHMP</p> <p>Mature stands were found to have 18.1% of the area covered by gaps, and old growth had 13.1%.</p> <p>Median gap size in mature stands was 19 square meters . Old growth (OG) was 85 square meters.</p> <p>Gap diameter to canopy height ratios varied between 0.05 to 0.4</p> <p>Gaps studied in old growth were initiated at least 50 years ago.</p> <p>Seedlings were more common in gaps than under forest canopies. Regen was about 3x more common in mature forest gaps than the surrounding forest; in OG, seedlings were 9x more common than in surrounding OG forest. Even so, the greatest number of seedlings/100m squared was only 16, for Hemlock.</p> <p>Gap formation rates are 0.2% for OG and 0.3% for mature stands. The majority of gaps were over 25 years old, suggesting that the low rate of gap formation is paralleled by a low rate of gaps filling in.</p> <p>Shade-intolerant species will reproduce in gaps 300 to 1000 square meters. Gaps were not typically large enough to have high light intensities at ground level. Douglas fir requires 750 to 1000 square meters for seedling establishment.</p> <p>In later stand development, when trees are near their maximum size, lateral branch growth does not likely play an important role in filling in a gap.</p> <p>Hemlock seedlings have been shown through numerous studies to reproduce well on rotted logs.</p>
189	<p>St. Clair, C.C., M. Belisle, A. Desrochers and S. Hannon. 1998. Winter Responses of Forest Birds to Habitat Corridors and Gaps. <i>Cons. Ecol.</i> Vol. 2, Article 13.</p> <p>2 - Somewhat Relevant to Jackson WHMP</p> <p>Studied "gaps" in the sense of gaps between forested areas and their effect on willingness of birds to cross from one forested area to another. Chickadees were willing to cross a 25m opening, but as distance increased they chose detours through adjoining forest or habitat corridors. A gap of 200m was only crossed if no alternative was available.</p>
288	<p>Steeger, C. and M. Machmer. 1995. Use of Trees by Cavity Nesters in Managed and Unmanaged Interior Cedar-Hemlock Stands of Southern B.C. In: Bradford, P., T. Manning and B. l'Anson eds. <i>Wildlife Tree/ Stand-Level Biodiversity Workshop Proceedings</i>. Victoria, B.C. October 1995. 45-54.</p>

	<p>2 - Somewhat Relevant to Jackson WHMP Study conducted in SE B.C.</p> <p>Mean dbh for active nest snags was 41.8cm Mean height for active nest snags was 20.6m</p> <p>Mean dbh for feeding trees was 30.3 cm Mean height for feeding trees was 13.4m</p> <p>Mean dbh of Douglas-fir used for bat roosts was 46.0 cm; mean height was 24.0 m, and a vast majority (55.6%) of these roost were in woodpecker cavities.</p> <p>Authors caution that if logging occurs during the main breeding season (May - July) that nestling bird and mammals occupying the nest trees will be unintentionally destroyed.</p>
223	<p>Stevenson, S.K., Keisker, D.G. 2002. Evaluating the effects of partial cutting on wildlife trees and coarse woody debris. In Gen. Tech. Rep. PSW-GTR-181. USDA Forest Service.</p> <p>2 - Somewhat Relevant to Jackson WHMP</p>
108	<p>Stewart, G. H. 1986. Forest Development in Canopy Openings in Old-Growth Pseudotsuga Forests of the Western Cascade Range, Oregon. Can. J. For. Res. 16:558-568.</p> <p>1 - Very Relevant to Jackson WHMP From 1986, but relevant in terms of vegetation response within gaps.</p> <p>For silver fir and hemlock to reach the main canopy, gaps are considered by many researchers to be a requirement.</p> <p>Over 80% of hemlock seedlings had become established on elevated surfaces, such as CWD.</p> <p>Direct light may be more important for the development of understory plants, including tree seedlings, than the amount of total light.</p> <p>Silver fir seedlings were found to be more abundant in gaps due to 3 primary reasons: 1) hemlock is more susceptible to snow damage, 2) hemlock establishes on rotten logs, so suitable sites may be limited, and 3) hemlock seedlings are susceptible to low soil moisture in the summer.</p>
105	<p>Stewart, G.H. The Influence of Canopy Cover on Understory Development in Forests of the Western Cascade Range, OR, USA. Vegetatio 76:79-88.</p> <p>1 - Very Relevant to Jackson WHMP In burned areas where Douglas fir regenerated quickly, Hemlock and Silver fir quickly followed, however, if Hemlock established first, other species either did not regenerate or did so only very slowly until canopy openings were formed.</p> <p>In stands where fire had not occurred for several centuries, regeneration only occurred in areas of tree-fall gaps or under Douglas fir canopies; regeneration rarely occurred under Hemlock canopies.</p> <p>Dominance of Hemlock in the canopy has a strongly negative effect on understory cover.</p> <p>Canopy gaps were found to be significantly more common in mixed canopy and Douglas fir stands than in Hemlock stands.</p> <p>Hemlock seedlings were most often found on woody debris such as old Douglas fir logs and stumps.</p>

	<p>Understory plants such as <i>Vaccinium alaskaense</i>, which typically grows to 4 feet or more, were commonly found to be less than 9" tall under Hemlock canopies.</p> <p>Percent frequency, cover and species richness of many common understory species was also reduced under Hemlock canopies versus Douglas fir canopies or canopy openings.</p>
304	<p>Stubblefield, T.C. 1995. 1995 Monitoring and Evaluation Report: Gifford Pinchot National Forest. USDA Forest Service, Gifford Pinchot NF. 47p.</p> <p>2 - Somewhat Relevant to Jackson WHMP</p> <p>Primarily provides information on timber sales and whether they met goals for wildlife habitat provisions; but also provides basic information as to general rules for implementation of the Forest Rules.</p> <p>To provide suitable habitat a snag needs to be at least 17 inches in diameter and 40 feet high.</p> <p>If the average diameter of the stand was too small, making it impossible to meet the snag and down log size requirements specified by current guidelines, the purchaser is required to leave the largest trees when the required diameter is not available.</p>
38	<p>Torgerson, R, Duncan, S. 2002. When the trees die. <i>The World & I</i>. 140-147.</p>
65	<p>US Forest Service. 1999. Dead and dying trees:essential for life in the forest. <i>Science Findings</i> 20. November 1999.</p> <p>1 - Very Relevant to Jackson WHMP</p> <p>Mike: SNAGS:</p> <p>To create a hollow cavity, the decay process must begin early in the life of a live tree. Entrances used by wildlife are typically between 30 and 80 feet off the ground. Recent studies show that an increase in the number of snags per acre is needed if snags providing roosting, nesting, foraging, denning, shelter and resting are to be provided. Current Forest Service e guidelines and standards are inadequate.</p>
96	<p>USDA Forest Service, PNW Region. 1990. Final EIS, Land and Resource Management Plan, Mt Baker-Snoqualmie National Forest, Appendix H.</p> <p>1 - Very Relevant to Jackson WHMP</p> <p>Mike:</p> <p>Habitat requirements for the PWP to be used in their analyses include a minimum of 2 hard snags/acre $\geq 12"$ dbh within a 300 acre reproductive area for feeding. Forty-five of the 600 (0.15/ac) snags required should be $\geq 20"$ dbh.</p> <p>For the Pine Marten, providing at least these same minimums would ensure that adequate CWD is available for reproducing and feeding.</p>
285	<p>USDA Forest Service. 1994. Standards and Guidelines for Management of Habitat for Late-Successional and Old-Growth Forest Related Species Within the Range of the Northern Spotted Owl, Attachment A to the Record of Decision for Amendments to Forest Service and Bureau of Land Management Planning Documents Within the Range of the Northern Spotted Owl.</p> <p>1 - Very Relevant to Jackson WHMP</p> <p>Mike's notes:</p> <p>Adequate numbers of large snags and green trees are especially critical for bats because these trees are used for maternity roosts, temporary night roosts, day roosts, and hibernacula. Large snags and green trees should be well distributed throughout the matrix because bats compete with primary excavators and other species that use cavities. Day and night roosts are often</p>

	<p>located at different sites, and migrating bats may roost under bark in small groups. Thermal stability within a roost site is important for bats, and large snags and green trees provide that stability. Individual bat colonies may use several roosts during a season as temperature and weather conditions change. Large, down logs with loose bark may also be used by some bats for roosting.</p> <p>Removal of snags following disturbance can reduce the carrying capacity for these species for many years.</p> <p>Regarding green tree areas, for many species, benefits will be greatest if trees are retained in patches rather than singly. Because very small patches do not provide suitable microclimates for many of these organisms, patches should generally be larger than 2.5 acres.</p> <p>To the extent possible, patches and dispersed retention should include the largest, oldest live trees, decadent or leaning trees, and hard snags occurring in the unit. Patches should be retained indefinitely.</p> <p>As a minimum, snags are to be retained within the harvest unit at levels sufficient to support species of cavity-nesting birds at 40 percent of potential population levels based on published guidelines and models. The objective is to meet the 40 percent minimum standard throughout the matrix, with per-acre requirements met on average areas no larger than 40 acres. To the extent possible, snag management within harvest units should occur within the areas of green-tree retention. The needs of bats should also be considered in these standards and guidelines as those needs become better known.</p> <p>Specifically, the Scientific Analysis Team recommends that no snags over 20 inches dbh be marked for cutting. The Scientific Analysis Team recognizes, however, that safety considerations may prevent always retaining all snags.</p> <p>Site-specific analysis, and application of a snag recruitment model (specifically, the Forest Service's Snag Recruitment Simulator) taking into account tree species, diameters, falling rates, and decay rates, will be required to determine appropriate tree and snag species mixes and densities. If snag requirements cannot be met, then harvest must not take place.</p> <p>Snag requirements are developed by the National Forests and BLM Districts for specific forest cover types, and these may be further broken down by geographic location. The intent is to tailor the requirements to those species that are actually expected to occur in an area.</p> <p>The most current available research will be used to determine to what degree the requirements for these other species are met by these snags or whether additional snags are needed to meet these other species objectives.</p>
71	<p>Van Pelt, R. 1995. Understory Tree Response to Canopy Gaps in Old-Growth Douglas-fir Forests of the Pacific Northwest. Seattle, WA. Univ. of WA. PhD Dissertation; 237p. 1 - Very Relevant to Jackson WHMP Master's thesis available from UW library.</p> <p>Variability in the canopy was highly correlated with understory light levels and shrub cover values.</p> <p>Spatial patterns of regeneration trees were poorly correlated with canopy height, canopy density and location of gaps</p> <p>Light environment is highest 18-20m north of the gap center.</p>

	<p>Understory trees that responded to gap formation did so within 5 years, but many did not show a response.</p> <p>Shrub and herb cover showed stronger correlation with canopy gaps and were more adaptable to changes in the canopy environment.</p> <p>Noted that Spies et al 1990 reported that median gap size in OG DF forests was 85m² (765ft²), small enough that only shade tolerant species can take advantage.</p> <p>Hemlock crowns are more densely packed with needles than Douglas-fir.</p> <p>High latitude of Pacific forests and the height of the canopy allow light to filter in at relatively high angles.</p> <p>Understory tree location was poorly correlated with gap location, but shrub location was better correlated with gap location.</p> <p>Several natural gaps were analyzed to determine the gap initiation year and cause, if possible. One gap nearly doubled in size over a 40 year period, with at least 3 separate events causing overstory tree mortality.</p> <p>Trees may take several years to reveal effect of release from competition when a neighbor dies.</p> <p>Highest branch growth of residual trees around experimental gaps (0.35ha) was by the third growing season and was south of center, where diffuse light levels were high, but direct light levels were low.</p> <p>Trees in direct light suffered higher rates of mortality and retained needles for a shorter duration.</p> <p>The northern part of the gap exhibited the greatest change in biological factors measured; this area had the highest soil light and soil temperature levels, and consequently the highest mortality and needle loss on surviving trees.</p>
110	<p>Van Pelt, R. And J. F. Franklin. Response of Understory Trees to Experimental Gaps in Old-Growth Douglas-Fir Forests. Ecol. Appl. 9: 504-512.</p> <p>1 - Very Relevant to Jackson WHMP</p> <p>Artificial gaps, 0.2 ha in size were created.</p> <p>Understory trees may require several years to acclimatize to overstory removal (3 years seemed common in this study).</p> <p>Light levels in the northern portions of the gaps increased by up to 500%, and soil temps at the surface increased by as much as 25 degrees C.</p> <p>This caused severe stress to many understory trees. Within 3 years, understory trees within the gaps had developed sun needles and were responding positively to the increased light.</p> <p>Understory trees experienced up to 1 month of additional growing season due to the removal of overstory trees.</p> <p>Areas of gaps that receive high diffuse light showed the highest growth rates, since they were not stressed by a great increase in direct light. The highest mortality was in areas that received an increase in direct light.</p> <p>Since a great deal of light reaching the forest floor in the northern hemisphere is from oblique</p>

	angles, tree response to canopy gaps may be greatest outside of the gap.
298	<p>Vesho, I. 2000. Influence of Old-Growth Canopy Gaps on Microclimate, Litter Decomposition, and Soil Nitrogen Dynamics in Olympic National Park, WA. Seattle, WA. Univ. of WA Master's Thesis; 80 p. 2 - Somewhat Relevant to Jackson WHMP Available from UW library.</p> <p>Relevant geographically and temporally, but focuses primarily on the effect of canopy gaps on soil moisture and temperature, litter decomposition rates and soil nitrogen mineralization.</p>
309	<p>WA. Dept. of Fish & Wildlife. January 2005. WDFW Management Recommendations for Washington's Priority Species: Pileated Woodpecker. 1 - Very Relevant to Jackson WHMP WDFW PHS Birds Vol IV Pileated WP p 29-1 updated 2003 http://wdfw.wa.gov/hab/phs/vol4/birdrecs.htm</p> <p>The breeding and nesting periods of the pileated woodpecker extends from late March to early July (Bull et al. 1990).</p> <p>Most nest cavities were observed in hard snags with intact bark and broken tops, or live trees with dead tops.</p> <p>Pileated woodpeckers may use up to 11 roosts over a 3-10 month period; however, some individuals will use one roost for a long period before switching to a new roost, while others regularly switch among several roosts (Bull et al. 1992b).</p> <p>Home ranges vary in size within the Pacific Northwest, ranging from 407 ha (1,006 ac)/breeding pair (data collected between June and March) in northeastern Oregon (Bull and Holthausen 1993), 480 ha (1,186 ac)/breeding pair during the summer in the central Oregon Coast Range (Mellen et al. 1992), and 863 ha (2,132 ac)/breeding pair annually on the Olympic Peninsula (Aubry and Raley 1996). The home range figures reported in the central Oregon Coast Range are likely smaller than the actual year-round home range for the pileated (Mellen et al. 1992).</p> <p>The removal of large snags, large decaying live trees and downed woody debris of the appropriate species, size and decay class eliminates nest and roost sites and foraging habitat. Intensively managed forests typically do not retain these habitat features (Spies and Cline 1988).</p> <p>fragmentation of forested habitat may lead to reduced population density and increased vulnerability to predation as birds are forced to fly between fragmented forested stands;</p> <p>General Recommendations Specific management prescriptions should be developed for actions that will be undertaken at the home range scale</p> <p>Trees, snags and stumps with existing pileated nest cavities and foraging excavations should be retained (Bonar 2001).</p> <p>Properly conducted uneven-aged management of forest stands can create adequate canopy closure and sufficient large snags and large decaying live trees to maintain suitable nesting and roosting habitat for pileated woodpeckers. Defective or cull trees can be retained during commercial thinning operations, or these can be recruited to become snags in subsequent rotations (Neitro et al. 1985). Because of the difficulties in recruiting large snags in managed forests (Wilhere 2003), one of the most</p>

	<p>effective means to improve snag densities may involve extending the length of harvest rotations (Neitro et al. 1985).</p> <p>The following set of recommendations is based primarily on average (rather than minimum) standards.</p> <p>The PIF (Partners in Flight) recommendations for managed coniferous forests (stands with >70% conifer stems) of about 60 years of age or older include maintaining >70% canopy closure and an average of >5 nest snags/10 ha (2 snags/10 ac) that are >76 cm dbh (30 in). In areas used for both nesting and roosting, an average of 18 large snags/ha (7 snags/ac) and 8 decaying large trees/ha (3 trees/ac) should be retained (Aubry and Raley 2002b).</p> <p>trees between 155 and 309 cm dbh (61-122 in) should be retained for roosting. In addition, an average of 30 foraging snags/ha (12 snags/ac) (mix of hard and soft snags) should be provided in the following size classes (see Table 3; Altman 1999).</p> <p>Adequate snag densities are defined as the combination of nesting, roosting and foraging snag numbers (see above).</p> <p>Suggested number of foraging snags to retain:</p> <p>10-20" = >= 7/ac 20-30" = >= 3/ac >30" = >= 2/ac</p> <p>General Recommendations</p> <ul style="list-style-type: none"> •Maintain large snags and large decaying live trees for nesting and roosting •Retain naturally formed stumps and numerous large logs in various stages of decay to improve foraging habitat •Use average size standards (rather than minimums) for managing pileated woodpecker habitat components (e.g., nest size standards). <p>Western Washington</p> <ul style="list-style-type: none"> •Maintain managed coniferous forests (stands with >70% conifer stems) of about 60 years of age or older at >70% canopy closure and an average of >5 nest snags/10 ha (2 snags/10 ac) that are >76 cm dbh (30 in) •Retain an average of 18 large snags/ha (7 snags/ac) and 8 decaying large trees/ha (3 trees/ac) in areas used for both nesting and roosting •Retain trees >27.5 m (>90 ft) in height to provide nesting and roosting structures. Trees between 155 and 309 cm dbh (61-122 in) should be retained for roosting •Retain an average of 30 foraging snags/ha (12 snags/ac)
305	<p>WA. Dept. of Fish & Wildlife. January 2005. WDFW Management Recommendations for Washington's Priority Species: Cavity Nesting Ducks. 2p.</p> <p>1 - Very Relevant to Jackson WHMP</p> <p>Recommend a minimum density of 5 potential nest cavities/acre within 0.5 miles of wetlands.</p> <p>Separate nest boxes by 150' or more to reduce predation.</p>
306	<p>WA. Dept. of Fish & Wildlife. January 2005. WDFW Management Recommendations for Washington's Priority Species: Vaux's Swift. 1p.</p> <p>1 - Very Relevant to Jackson WHMP</p> <p>Timber management plans should provide for long rotations (>200 years) and retain large hollow snags and live defective trees for future snag replacement (>20" dbh).</p>

	<p>Large defective trees with signs of decay (top rot, broken tops, fungal conks, dead branch stubs and other defects) should be retained.</p> <p>Chimney trees occupied by nesting or roosting swifts should not be disturbed between May and September.</p>
24	<p>Waldien, D.L., J.P. Hayes and B.E. Wright. 2003. Use of Conifer Stumps in Clearcuts by Bats and Other Vertebrates. NW Sci. 77: 64-71.</p> <p>1 - Very Relevant to Jackson WHMP</p> <p>Inventories of stumps in recent clearcuts found that use was restricted to warm/dry weather, when thermoregulation by bats and amphibs/reptiles would be beneficial.</p> <p>Even bats known to roost in stumps (Long-eared myotis) were less common if snags were at low densities within 2.5 km of the site.</p> <p>Limited snag resources may limit populations of forest-dwelling bats.</p>
139	<p>Walter, S. T. and C. C. Maguire. 2005. Snags, Cavity-Nesting Birds, and Silvicultural Treatments in Western Oregon. JWM 69:1578-1591.</p> <p>1 - Very Relevant to Jackson WHMP</p> <p>Large snags (>50cm dbh & 15m tall) are used disproportionately more than small snags.</p> <p>Experiment included creation of snags in clusters (8-12 snags) and scattered snags in 3 stand treatments: group-selection (33% volume removed in 0.2 to 0.6 ha patches), two-story stands (75% volume removed uniformly, leaving 20-30 scattered mature trees/ha, and clearcuts (with 1.2 green trees/ha retained).</p> <p>Created snags were saw-topped 10-12 years prior to study.</p> <p>19.9% of created snags were noted to have cavity-nesting.</p> <p>Live-topped conifers had low amounts of cavity excavation (7.8%), no active nests and low amounts of sapwood decay.</p> <p>1 active cavity was noted/4.9 created snags.</p> <p>Active cavities were 2.9x more abundant in clearcuts than in group-selection cuts.</p> <p>No difference in number of active nests or evidence of foraging found between clumped and scattered snags.</p> <p>Cavity nesting birds did not respond to Silvicultural treatment or snag arrangement, but active cavity numbers did increase from group-selection to 2-story to clearcut stands.</p> <p>Created snags with intact branches had higher incidence of cavity excavation.</p> <p>Snags in 2-story stands had 1.7x more cavities than snags in group-selection stands; no difference was found between group-selection and clearcuts or between 2-story and clearcuts.</p> <p>2-story stands and clearcuts with similar snag densities had more cavity nests, higher species richness, greater species diversity, and more similar communities of cavity-nesting birds compared to group-selection stands. Open canopy stands typically see increased vertical and horizontal structural diversity resulting from increased light input. This results in longer tree crowns and epicormic branching. These structures and snags provide habitat for many insects that are eaten by cavity-nesting birds. ***The low number of foraging events observed on snags indicates that much feeding activity occurs elsewhere.</p>

	<p>Chainsaw-topped snags began to be used for nesting within 4 to 6 years after creation.</p> <p>Topped snags were consistently more often used for foraging and nesting within the first 9 years due to accelerated decay caused by exposure of the inner wood following crown removal.</p> <p>**Silvicultural treatments resulting in open-canopy stands of mature conifers promote diverse stand structures that support more species and greater abundance of cavity-nesting birds than found in closed-canopy forests with equal snag densities.</p> <p>** A mix of stand conditions is required to meet the needs of all species capable of populating an area.</p>
232	<p>Walters, E.L. and E.H. Miller. 2001. Predation on Nesting Woodpeckers in British Columbia. <i>Can. Field Nat.</i> 15:413-419.</p> <p>3 - Not Relevant to Jackson WHMP</p> <p>Primarily discusses predation by bears, deer mice and house wrens as well as long-tailed weasel on cavity nesting species, but no recommendations as to sizes or species of trees to attempt to reduce this.</p>
234	<p>Waterhouse, F.L., A. S. Harestad and P. K. Ott. 2002. Use of Small Streams and Forest Gaps for Breeding Habitats by Winter Wrens in Coastal British Columbia. <i>Northwest Sci.</i> 76:335- 346.</p> <p>2 - Somewhat Relevant to Jackson WHMP</p> <p>Wrens selected streams $\leq 10\text{m}$ wide, even though those $<5\text{m}$ wide tended to dry up during the breeding season.</p> <p>The area within 5m of stream banks was most important for winter wren nest sites.</p> <p>Canopy gaps were also found to be important habitat sources in both upslope and riparian areas due to the nature of gap creation (rootwads, stumps, down trees etc that are used as song perches).</p>
175	<p>Weikel, J.M. and J.P. Hayes. 1999. The Foraging Ecology of Cavity-Nesting Birds in Young Forests of the Northern Coast Range of Oregon. <i>Condor</i> 101:58-66.</p> <p>1 - Very Relevant to Jackson WHMP</p> <p>Although woodpeckers sometimes do forage on the same types of snags that they use for nesting (Mannan et al. 1980), there is no information indicating whether management strategies that focus only on nesting habitat would provide adequate foraging habitat to support woodpecker populations. Furthermore, current management strategies rarely consider foraging needs of cavity-nesting species other than woodpeckers.</p> <p>All four species of cavity-nesting bird showed selectivity in use of foraging substrates. Chestnut-backed Chickadees foraged frequently on live trees (Fig. 1), and was the only species observed foraging on shrubs. When foraging on shrubs, they were observed exclusively, and about equally, on vine maple and huckleberry. they selected hardwoods over conifers in relation to their availability (Table 2).</p>

Red-breasted Nuthatches foraged mostly on live conifers, but occasionally used snags (Fig. 1), and selected live trees that had larger diameters and fewer crown connections than did randomly chosen live trees (Table 2).

The only species to forage substantially on snags and logs was the Hairy Woodpecker (Fig. 1). When foraging on live trees, Hairy Woodpeckers selected deciduous over coniferous trees and selected trees that had larger diameters than did randomly chosen live trees (Table 2).

Hairy Woodpeckers selected snags that had larger diameters than did randomly chosen snags, and selected logs that had larger diameters

Chestnut-backed Chickadees, Red-breasted Nuthatches, Brown Creepers, and Hairy Woodpeckers showed selectivity in use of foraging substrates. Deciduous trees, large diameter conifers, large diameter heavily decayed snags, and large diameter heavily decayed logs were important components of foraging habitat.

Red alder, the most abundant deciduous tree species in our study area, may support a high diversity and abundance of arthropods (Furniss and Carolin 1977, Oboyski 1995). Many of the orders of arthropods found on red alder are important in the diet of adult and nestling Chestnut-backed Chickadees (Lepidoptera, Hymenoptera, and Hemiptera; Beal 1907, Kleintjes and Dahlsten 1992) and adult Hairy Woodpeckers (Coleoptera; Beal 1911, Otvos and Stark 1985). Schimpf and MacMahon (1985) found that arthropod density was higher in canopies of deciduous aspen forests than in canopies of coniferous forests. Because abundance of arthropods may be higher on deciduous than on coniferous trees, deciduous trees within a conifer-dominated landscape likely provide valuable foraging habitat for cavity-nesting birds.

Management of nesting resources without regard to foraging resources is probably inadequate to provide habitat for cavity-nesting birds. We contend that in order to effectively manage habitat for cavity-nesting birds, foraging habitat, as well as nesting habitat, should be provided. In young conifer-dominated forests of the Pacific Northwest, patches of hardwoods, large diameter conifers, and large diameter snags and logs

	<p>should be retained when logging. Legacy snags (large diameter snags from the previous stand) in young forests are especially important resources for cavity-nesting birds both as nesting (Mannan et al. 1980, Lundquist and Mariani 1991) and foraging substrates (Mannan et al. 1980, this study)</p>
109	<p>Wender, B.W., C. A. Harrington and J.C. Tappeiner II. Flower and Fruit Production of Understory Shrubs in Western WA & OR. NW Sci. 78:124-140. 1 - Very Relevant to Jackson WHMP This study only considered a gap to be such when the ratio of gap width to canopy height was 1.0 or greater.</p> <p>Flowering was not observed on vine maple <10 years old (y/o), but was seen on stems up to 64 y/o. Hazelnut and huckleberry also flowered at ages > 20 y/o.</p> <p>Heavily flowering shrubs were more common in gaps than under intact canopies.</p> <p>Flower production of evergreen huckleberry (<i>V. ovatum</i>) increased as the overstory of conifers increased, but decreased as the crowns of overstory trees overlapped.</p> <p>Intensity of commercial thinning was strongly correlated to production outcome for Oregon grape, ocean spray, red huckleberry, and was strongest for salal.</p> <p>Moderate thinnings, followed by heavy, then light thinning treatment were found to have the greatest impact on the probability of shrub flowering.</p> <p>Red huckleberry did not respond differently to varying levels of thinning.</p> <p>Plant size and age is more important in determining the likelihood of flowering for common understory shrubs than overstory density.</p> <p>The resources available also impact flower/fruit production by influencing the size of the plant, thus, canopy gaps should increase the amount of resources available to the plants and should in turn lead to increased flower/fruit production.</p> <p>Woody perennials have the ability to store resources for long periods of time, and therefore gap-induced plant growth may be hard to predict.</p> <p>Responses to gap creation or thinning may be delayed if conditions during the growing season are unfavorable (i.e. precipitation).</p> <p>Older legacy shrubs, or pockets thereof, may needed to be protected within a stand to ensure that large individuals are maintained into the next forest generation.</p>
22	<p>Western Forestry and Conservation Association. 2006. Managing for Wildlife Habitat in Westside Production Forests. Proceeding of a Workshop on October 18, 2006. Vancouver, WA. 1 - Very Relevant to Jackson WHMP</p>
211	<p>Wilhere, G.F. 2003. Simulations of snag dynamics in an industrial Douglas-fir forest. Forest. Ecol. And Manage. 174(1):521-539. 2 - Somewhat Relevant to Jackson WHMP Attempting to combine 4 existing snag computer simulation models into one meaningful model; presents little in the way of results.</p>

	<p>Computer simulation that integrates a snag model and FVS forest growth model. The snag model was developed by averaging the outputs of 4 independently created snag models for Douglas-fir snags in forests west of the Cascade Crest in OR, WA and BC.</p> <p>Results of running the models for management practices show the snag populations for 5 to 10 yrs, mean densities of snags of different sizes per decade, soft snag density per decade. Snag recruitment curves were generated, showing the number of snags that must be retained to produce desired snag density. The mean density of snags per decade produced under the typical silvicultural regime was projected to be about 20% of that found in unmanaged stands. The density of large snags was projected to be less than 1% of that found in unmanaged stands.</p>
256	<p>Wilson, S.M., Carey, A.B. 2000. Legacy retention versus thinning; influences on small mammals. <i>Northwest Science</i> 74(2):131-145.</p> <p>2 - Somewhat Relevant to Jackson WHMP</p> <p>Thinned areas had 1.5x the individual mammals and 1.7x the mammal biomass versus forests that were harvested but retained legacies from the previous forest (live trees, snags, cwd).</p> <p>Thinned stands showed a greater abundance, biomass and diversity of small mammals compared to legacy stands, but neither type of management supported the complete small-mammal community found in old growth forests.</p> <p>***authors suggest that combining thinning and legacy retention could provide more benefits than either of the individual strategies tested here.</p>
98	<p>Zarnowitz, J.E. and D.A. Manuwal. 1985. The Effects of Forests Management on Cavity-Nesting Birds in Northwestern WA. <i>J. Wildl. Manage.</i> 49:255-263.</p> <p>1 - Very Relevant to Jackson WHMP</p> <p>Study was conducted on the Olympic National Forest in 1980 but provides recommendations for snag allotments as well as densities of cavity nesting species. Four different successional stages were evaluated for their snag densities and corresponding secondary cavity-nesting species (SCN). Populations of SCN increased with increasing snag densities. Hairy woodpeckers were noted to select Hemlock for their nest sites. When compared to mean dbh of all snags, the average dbh of active nest trees was significantly greater.</p> <p>Densities of primary cavity nesters (PCN) and SCN considered (Vaux's Swift, Northern Flicker, Pileated & Hairy woodpeckers) varied between 4.9 and 9.8 pairs/40ha in 60-120 yr old stands containing roughly 12-60 hard snags/ha. In old growth stands, populations ranged from 5.4 to 6.3/40 ha and contained roughly 30-59 hard snags/ha. Both the density and the species diversity of cavity nesting birds increased as the density of snags increased.</p> <p>The average nest tree was 16m tall, versus the average height of all sampled snags (9.6m).</p> <p>Management recommendations:</p> <ul style="list-style-type: none"> - Retain minimum of 6 hard and 3 soft snags/ha harvested. This is the minimum for maintaining cavity nesting bird populations. - "The bulk of snags" should be greater than 50cm as well as some >23cm and some > 75cm dbh in all successional stages. - A mixture of snag species should be left, especially hemlock and Douglas-fir.

Streams, Wetlands and Buffer Zones

113	<p>Adams, M.J. 1999. Correlated factors in amphibian decline: exotic species and habitat change in western Washington. <i>J. Wildl. Manage.</i> 63(4):1162-1171.</p> <p>2 - Somewhat Relevant to Jackson WHMP</p> <p>Decline of red-legged frogs in western Washington linked to introduced fish associated with permanent wetlands. Conservatino of more ephemeral wetland habitats may benefit some native amphibians and also reduce the threat of exotic fish and bullfrogs.</p>
261	<p>Bisson, P.A. et al. 2002. Influence of site and landscape features on vertebrate assemblages in small streams. In: Johnson, A., Haynes, R. eds. <i>Proc. of the wood compatibility initiative workshop</i>. Gen Tech. Rep. PNW- GTR-563. Portland, OR: USDA Forest Service. Pac. NW. Res. Stn.</p> <p>3 - Not Relevant to Jackson WHMP</p> <p>Field study in 62 headwater streams on the Olympic Peninsula. Riparian Ecosystem Management Study (REMS).</p> <p>Site-level features included stream habitat type, channel substrate and riparian forest condiition canopy density, % riparian early-seral forest, % riparian mid-seral forest, % riparian late-seral forest). Landscape-level features included forest age (early-, mid-, late-seral), drainage characteristics (drainage density, watershed area), elevation, road density, and landslide frequency.</p> <p>Two major headwater vertebrate groups - fishes (cutthroat trout, torrent sculpin, coast range sculpin and amphibians(tailed frog, Cope's giant salamander, torrent salamander.</p> <p>Stream-dwelling amphibians influenced by riparian and watershed features and less affected by in-stream habitat. Stream-dwelling amphibians negatively affected by timber removal near streams. They preferred streams with late-seral riparian and uplands forests, low road density. Buffers of old-growth trees provided habitat refugia for some spp and were source areas for recolonization.</p> <p>The study did not establish a clear relationship b/n riparian forest characteristics and fish abundance in streams.</p> <p>Relationship b/n forest management and integrity of aquatic and riparian systems is complex, and it would be difficult to tailor management actions at the site level to produce desired changes in small stream-dwelling vertebrates at the population level. Changes in riparian forest at the landscape level, however, may influence populations. E.g., the percentage of a watershed in late-seral forest, the time since the last major disturbance, or road density may be important to aquatic- and riparian-associated vertebrates, but they are insufficient by themselves to explain population changes.</p>
141	<p>Bury, R.B., Corn, P.S. 1991. Sampling methods for amphibians in streams in the Pacific Northwest. Gen. Tech. Rep. PNW-GTR-275. Portland, OR: USDA Forest Service, Pac. NW Res. Stn. 29 p.</p>
73	<p>Castelle, A.J., Conolly, C., Emers, M., Metz, E.D., Meyer, S., Witter, M., Mauermann, S., Erickson, T., Cooke, S.S. 1992. Wetland Buffers: use and effectiveness. Olympia, WA: WA St. Dept. of Ecology, Shorelands & Coastal Zone Mgt. Prgm. Publ.# 92-10.</p>
142	<p>Corn, P.S., Bury, R.B. 1990. Sampling Methods for terrestrial amphibians and reptiles. Gen. Tech. Rep. PNW-GTR-256. Portland, OR: USDA Forest Service, Pac. NW Res. Stn. 34 p.</p>
331	<p>Cowardin, L.M., Carter, V., Golet, F.C., LaRoe, E.T. 1979. Classification of wetlands and deepwater habitats of the Unites States. FWS/OBS-79/31, US Fish and Wildlife Service, Office of Biological Services, Washington, D.C.</p>

132	Hayes, M.P, Jennings, M.R. 1986. Decline of ranid frog species in western North America: are bullfrogs (<i>Rana catesbeiana</i>) responsible? <i>J. Herpetol.</i> 20(4):490-509. Predation by both bullfrog and introduced fishes supported by this review; fish predation may be more significant.
332	Hruby, T. 2004. Washington State wetland rating system for western Washington -- Revised. Washington St. Dept. of Ecology. Publ. #04-06-025. 2 - Somewhat Relevant to Jackson WHMP
84	Johnson, D.H., O'Neil, T.A., managing dirs. 2001. <i>Wildlife-Habitat Relationships in Oregon and Washington</i> . Corvallis, OR: Oregon St. Univ. Press.
74	Knutson, K.L., Naef, V.L. 1997. <i>Management recommendations for Washington's priority habitats: riparian</i> . Olympia, WA: WA St. Dept. Fish & Wildl. 181 p. 1 - Very Relevant to Jackson WHMP Management recommendations for very wide range of activities, including many related to habitat characteristics for fish and wildlife. Required habitat characteristics for riparian zone fish and wildlife habitats: *Connectivity *Vegetation composition - A mosaic of successional stages and plant communities; in forested areas, a mixture of conifer and deciduous spp. in mixed age classes. Well developed herb and shrub layer. *Multiple canopy layers *Natural disturbance, e.g. flooding, channel meandering. *Snags *Woody debris, including large logs, stumps, root wads and branches in riparian zone and instream. *Shape - Irregular edge providing diverse interface between riparian and adjacent upland habitat types *Width - Appendix C provide information on riparian habitat functions and the widths needed to retain those functions. *Stream bank *Associated wetlands; oxbows and beaver ponds
86	Kusler, J.A., Kentula, M.E., eds. 1990. <i>Wetland Creation and Restoration: the status of the science</i> . Washington, DC; Island Press. 594 p.
193	Larsen, E.M., ed. 1997. <i>Management recommendations for Washington's priority species. Vol. III: Amphibians and Reptiles</i> . WA Dept. Fish and Wildl. Olympia, WA. 122 p. 1 - Very Relevant to Jackson WHMP
220	Nelson, C.R. 2004. <i>Effects of timber harvest and forest edges on abundance, viability, and physiology of understory plants in Pseudotsuga forests of western Washington</i> . PhD. Dissertation. Univ. of WA, Seattle, WA. 97 pp. 1 - Very Relevant to Jackson WHMP
260	Raphael, M.G. et al. 2002. <i>Effects of streamside forest management on the composition and abundance of stream and riparian fauna of the Olympic Peninsula</i> . In: Johnson, A., Haynes, R. eds. <i>Proc. Of the wood compatibility initiative workshop</i> . Gen Tech. Rep. PNW-GTR-563. Portland, OR: USDA Forest Service. Pac. NW Res. Stn.
87	Sheldon, D., Hruby, T., Johnson, P., Harper, K., McMillan, A., Granger, T., Stanley, S., Stockdale, E. 2005. <i>Wetlands in Washington State. Vol. 1: A Synthesis of the Science</i> . WA Dept. of Ecology Publ. 05-05-006. Olympia, WA.

	2 - Somewhat Relevant to Jackson WHMP
88	<p>Granger, R., Hrubby, T., McMillan, A., Peters, D., Rubey, J., Sheldon, D., Stanley, S., Stockdale, E. 2005. Wetlands in Washington State. Vol. 2: A Guidance for Protecting and Managing Wetlands. WA Dept. of Ecology Publ. 05-05-008. Olympia, WA.</p> <p>2 - Somewhat Relevant to Jackson WHMP</p> <p>Categorizes wetlands based on functions, sensitivity to disturbance, rarity. Recommendations for assigning buffer zone width based on these factors and others, such as buffer zone characteristics.</p>
35	Snohomish County. 2006. Revised draft summary of best available science for critical areas. March 2006. Snohomish County Planning and Development Services. Everett, WA.
75	Stevens, M.L., Vanbianchi, R. 1993. Restoring Wetlands in Washington: A guidebook for wetland restoration, planning and implementation. WA St. Dept. Ecology Publ. #93-17. Paging various.

Wildlife Species

113	<p>Adams, M.J. 1999. Correlated factors in amphibian decline: exotic species and habitat change in western Washington. <i>J. Wildl. Manage.</i> 63(4):1162-1171.</p> <p>2 - Somewhat Relevant to Jackson WHMP</p> <p>Decline of red-legged frogs in western Washington linked to introduced fish associated with permanent wetlands. Conservatino of more ephemeral wetland habitats may benefit some native amphibians and also reduce the threat of exotic fish and bullfrogs.</p>
307	<p>Altman, B., Hagar, J. 2006. Rainforest birds: a land manager's guide to breeding bird habitat in young conifer forests in the Pacific Northwest. U.S. Geological Survey, Sci. Investigations Report 2006-5304. 60 p.</p> <p>2 - Somewhat Relevant to Jackson WHMP</p> <p>Guide presents recommendations on the habitat conditions and features needed by breeding birds, and how breeding bird species respond to particular management activities.</p> <p>Effects of forest fragmentation.</p> <p>Patch size: Most birds that breed in young forests have fairly small territories, <5 ha per pair, but there are some exceptions. See linked table Some forest bird spp require patches of contiguous habitat much larger than their territory to be able to maintain a viable population. These spp are referred to as forest interior spp, or area-sensitive spp. Including brown creeper, chestnut-backed chickadee, golden-crowned kinglet, pileated woodpecker, red-breasted nuthatch, varied thrush, winter wren, and possibly Pacific-slope flycatcher. All these spp also occur in lower abundance in the latter stages of young forests (i.e. mid-successional) where it is suspected that the same area-sensitivity is applicable.</p> <p>Edge: Variable effects on different species, and not well understood.</p> <p>Connectivity: For birds associated with young conifer forests, less concern about connectivity unless the intervening habitat is non-forest.</p> <p>Deciduous vegetation: Highly important for 2 reasons: higher availability of cavities, and higher insect abundance.</p> <p>Strategizing among desired habitat features and bird spp. Often emphasize habitat needs of special status birds. May emphasize habitat diversity or bird species richness. A sound strategy combines these 2 approaches. Manage for species diversity at larger scales, and emphasize habitat conditions that meet the more specialized needs of priority spp at smaller scales. E.g., thinning to open canopy and promote development of a dense understory of various understory-associated spp, and then within a portion of the area emphasize the development of berry-producing shrubs/small trees like cascara or elderberry for band-tailed pigeon. Additionally, the open canopy in a large patch of the forest could be expanded, leaving scattered trees to provide habitat for olive-sided flycatcher.</p> <p>Planning for old forest habitat: Manage tree density early in stand development, before canopy closure to maintain a diverse stand structure throughout the life of the stand.</p> <p>Thinning. Short-term goals may be to increase structural diversity, or to create habitat for a particular set of spp. Long-term goals may include creating structural features typical of old forests, e.g. accelerate the growth of residual trees.</p> <p>Achieving old forest structure through thinning. Summarizes other studies.</p> <p>Thinning affects stem size, crown characteristics and vigor of trees, retention of lateral branches. Increase stand-level structural diversity, shrub response to light, tree seedling establishment.</p>

	<p>Bird response to thinning. See link</p> <p>Desired habitat features for breeding birds in young conifer forests. See link.</p> <p>Bird response to retention of forest structure. Only preliminary data available. Doesn't ameliorate for negative effects on the abundance of canopy dwelling spp like golden-crowned kinglet and hermit warbler.</p> <p>Habitat augmentation: **brush/slash piles used by American robin, dark-eyed junco, western bluebird, house wren, song sparrow, winter wren **snag cration **nest boxes</p> <p>Useful appendices: Successional stage nesting habitat relationships of breeding bird spp</p> <p>Relationships between thinning and breeding bird species abundance</p>
153	<p>Anthony, R. G., G. A. Green, E.D. Forsman & S.K. Mellen. 1996. Avian Abundance in Riparian Zones of Three Forest Types in the Cascade Mountains, Oregon. <i>Wilson Bull.</i> 108:280-291.</p>
176	<p>Artman, V. L. 2002. Effects of Commercial Thinning on Breeding Bird Populations in Western Hemlock Forests. <i>Am. Midl. Nat.</i> 149:225-232.</p> <p>2 - Somewhat Relevant to Jackson WHMP</p> <p>Compares bird populations and habitat structure in commercially-thinned and unthinned western hemlock stands on a tree farm in Pierce Co. 45 - 55 yo naturally-regenerated western hemlock stands (1270 live tph). CT treatments applied 3 to 5 yr before data collection; removed trees <30 cm dbh, resulting in 466 live tph. Canopy cover reduced from 89% to 73%. Small dead trees (<30 cm) almost as abundant as small live trees in unthinned stands--CT knocked the small dead tree inventory down to 76 tph. Snags >30 cm dbh reduced from 9 to 6 tph (not significantly different).</p> <p>Understory forb, grass and tree seedling components increased significantly post-CT. Moss, fern, shrub no significant difference.</p> <p>CWD volume increased post-CT</p> <p>12 bird species evaluated in this study. Total bird density did not differ between pre- and post-CT. Several bird spp responded positively to this CT: winter wren, dark-eyed junco, red-breasted nuthatch, chestnut-backed chickadee. Unclear why the latter 2 (cavity-nesters) increased post-CT. Similar result for these 2 spp reported by Hagar et al. (1996).</p> <p>Suggests managing with a mosaic of stand conditions (age classes and silvicultural treatments) to satisfy needs of most species. Repeated thinnings may be needed to maintain the mix of habitat conditions through a rotation.</p>
114	<p>Aubry, K.B. 1999. Amphibians in managed, second-growth Douglas-fir forests. <i>J. Wildl. Manage.</i> 64(4):1041-1052.</p> <p>2 - Somewhat Relevant to Jackson WHMP</p> <p>Second-growth timber stands managed for timber production had the same amphibian species present in unmanaged Douglas-fir stands. However, higher proportions of northwestern salamanders and western redback salamanders, and much lower proportions of tailed frogs were present in managed forests. No evidence that amphibian abundance was influenced by the amount of CWD, however, CWD in managed stands was not</p>

	<p>substantially lower than in unmanaged forests for any age classes in this study.</p> <p>The oldest age classes had the highest amphibian species richness, total biomass and total abundance, and higher abundances of ensatina and red-legged frog.</p> <p>Recommends thinning closed-canopy stands and extending rotation in managed stands.</p>
214	<p>Aubry, K.B., Halpern, C.B., Maguire, D.A. 2004. Ecological effects of variable-retention harvests in the northwestern United States: the DEMO study. <i>For. Snow Landsc. Res.</i> 78(1/2):119-137.</p> <p>2 - Somewhat Relevant to Jackson WHMP</p> <p>DEMO study (Demonstration of Ecosystem Management Options) conducted in 6 locations in sw OR and WA Douglas-fir stands ranging from 65 to 170 y.o. Data were collected prior to harvest (1994-1996), harvests in 1997-1998, initial post-treatment sampling completed in 2001.</p> <p>6 treatments on 13 ha unit, representing green tree retention systems.</p> <p>**100% retention (no harvest)</p> <p>**75% aggregated retention (all merch trees in three 1-ha circles were harvested--25% of the treatment unit)</p> <p>**40% aggregated retention (five 1-ha circles retained - 40% of the treatment unit - and all merch trees in the surrounding matrix were harvested</p> <p>**40% dispersed retention (dominant and co-dom trees retained in an even distribution throughout the unit. In each block, the basal area retained was equal to that retained in the 5 patches of the corresponding 40% aggregated-retention treatment)</p> <p>**15% aggregated retention (two 1-ha circles were retained - 15% of the treatment unit - and all merch trees in the surrounding matrix were harvested.</p> <p>**15% dispersed retention (dominant and co-dom trees retained in an even distribution throughout the treatment unit. In each block, the basal area retained was equal to that retained in the two patches of the corresponding 15% aggregated-retention treatment.)</p> <p>Post-harvest treatment:</p> <p>**6.5 snags/ha created in all harvested areas</p> <p>**Pre-existing CWD retained, but no prescription implemented to create additional material.</p> <p>**Reforestation (mix of spp) to achieve min. stocking of 312 tph at 5 yrs post-harvest</p> <p>Response variables</p> <p>**overstory and understory vegetation - will examine effects of GTR on forest structure and composition, and quantify veg changes to aid in understanding responses of associated organisms and processes.</p> <p>**ectomycorrhizal fungi</p> <p>**canopy arthropods</p> <p>**amphibians and forest-floor small mammals</p> <p>**bats</p> <p>**breeding birds</p> <p>Pre-publication summaries:</p> <p>Overstory and understory vegetation. Most groups of forest understory plants declined in abundance and richness more at 15 than at 40% retention. Changes within 1-ha aggregates were small on average, and declines in adjacent harvested areas were greater than those in the corresponding dispersed treatments. Forest herbs declined on the edges of the 1-ha aggregates. Late-seral herbs more frequently extirpated from harvested plots in the aggregated treatments than from plots in the dispersed treatments.</p> <p>Salamanders. Little evidence that level or pattern of retention strongly influenced salamander populations during the first few yrs post-harvest. Within aggregated-retention treatments, salamanders more frequently captured in uncut than in cut areas. Salamanders most abundant in areas where CWD and/or herb cover were high.</p>

	<p>Small mammals. Pattern of retention did not have consistently strong effects on small mammal abundance or community comp. Initial results indicate that 1-ha aggregates may function as short-term refuges for several interior-forest spp: red-backed voles.</p> <p>Bats. Variable-retention treatments created forest openings/reduce canopy density and increased use by some bat spp--perhaps concentrated their use in these openings. Furthermore, greatest impact on bat populations is probably loss of large trees and snags roosting habitat.</p> <p>Breeding birds. Variable responses depending on the species. In general, birds that feed or nest in tree canopy or feed in bark decreased at greater harvest levels, whereas spp associated with forest-edge or open habitats increased.</p> <p>Second round of post-treatment veg sampling scheduled for 2003 and 2004.</p> <p>For summary reports from individual studies see http://www.cfr.washington.edu.research.demo/research/r_invert.htm</p> <p>IUFRO meeting on Innovative Experiments for Sustainable forestry in Aug. 2004 in Portland</p>
42	<p>Aubry, K.B., Raley, C.M. 2002. Selection of nest and roost trees by pileated woodpeckers in coastal forests of Washington. J. Wildl. Manage. 66:392-406.</p> <p>1 - Very Relevant to Jackson WHMP</p> <p>PWP were tracked using radio telemetry, calling and ground searches over a 6 year period in coastal WA forests. A total of 25 nests and 144 roosts were found. Decadent live trees were used as often as snags for both nesting and roosting. Silver fir were preferred (selected for) for nesting and Cedar for roosting; Hemlock were selected against for both activities, but when they were used, 2/3 of the time they were decadent, but not dead. Nest snags typically were sound snags with intact bark and limbs still carrying small twigs/dead foliage.</p> <p>Nest trees average 101.2 cm dbh x 39.3 m tall. More than 3/4 of nest openings were within the canopy, and all nest openings in decadent trees were several meters above the highest live limb (an average of 4.6m above).</p> <p>Roost trees averaged 149 cm dbh x 36.5m tall. Most roost trees were Hemlock (52%) or Cedar (42%). Roost snags were most often (73%) in later stages of decay with broken tops (71%). When used for roosting, Cedar were usually live tress (77%). Roost openings averaged 23m above ground and in decadent trees were usually below the highest love limb.</p> <p>Preferences: Trees less than 17.5m tall were selected against for both nesting and roosting. Nest trees ranged from 65-154cm dbh but PWP were not selective among these sizes. Roost trees ranged from 65-309cm dbh but PWP preferred trees 155-309cm dbh, used trees 125-154 cm dbh in proportion to their availability and selected against trees 65 - 124cm dbh.</p> <p>Nesting and roosting plots had higher densities of decadent and large trees and greater tree species diversity than areas not chosen for nesting or roosting sites. The probability that a site would be chosen for nesting or roosting increased 300% for each additional decadent tree/0.4ha, 200% for each additional tree species/0.4ha, and 130% for each additional large snag/0.4ha.</p> <p>PWP foraging on logs was seldom seen, and when it was observed, it was usually on a log suspended off the ground.</p> <p>Recommendations for PWP in W Wa (from Nietro et al. 1985) are based solely on the requirements for nesting (6 hard snags \geq 63.5cm dbh/40.5 ha).</p>

	<p>In this study, PWP preferred decadent trees for both nesting and roosting, and used 7 roost trees each year, on average.</p> <p>Since living trees with heart-rot fungi will provide nesting and roosting habitat longer than a hard snag, managing for decadent trees in addition to snags would ensure that nesting and roosting habitat are available for a much longer period of time than managing solely for hard snags.</p>
43	<p>Aubry, K.B., Raley, C.M. 2002. The pileated woodpecker as a keystone habitat modifier in the Pacific Northwest. In W.F. Laudenslayer, Jr. (and others), tech. coords. Proceedings of the Symp. on the Ecology and Management of Dead Wood in Western Forests. PSW-GTA-181. Albany, CA: US Forest Service, Pacific SW Res. Stn. pp. 257-274.</p> <p>1 - Very Relevant to Jackson WHMP</p> <p>Mike - Snags:</p> <p>Recommendations for forest management in matrix lands covered by the NW Forest Plan:</p> <p>retain 15%+ of the harvested area as green tree reserves; 70% of which should be clumps 0.2 to 1.0 ha in size, the remainder dispersed either individually or small clumps > 0.2 ha in size. These clumps & dispersed groupings should be comprised of the largest, oldest, decadent or leaning trees and hard snags occurring within the unit. Snag management would primarily occur within these areas of green-tree retention.</p> <p>Bernice, table 3 provides CWD recommendations.</p>
19	<p>Aubry, Keith B. and Catherine M. Raley. Landscape-Level Responses of Pileated Woodpeckers to Forest Management and Fragmentation: A Pilot Study. Progress Report 1990 and 1991. USDA Forest Service PNW Research Station. January 8, 1992. 73p.</p> <p>1 - Very Relevant to Jackson WHMP</p> <p>Half of all PWP nest cavities were in snags with broken tops, and half in live trees with broken tops. 75% were in Hemlock, 25% in Cedar. Avg DBH of all nest trees was 97.0cm, and nest cavities averaged 37.6m high. 73% of all roost cavities were in Hemlock, 27% in Cedar. Mean number of ALL decadent trees greater than 5m tall was 22.33/ha, mean number of snags alone was 20.55/ha. Logs were relatively unimportant as a food source in this study area.</p>
134	<p>B.C. Ministry of Forests. 1992. Maintaining marten habitat in managed forests. Fish and Wildlife Branch, Thompson Nicola Region and Wildlife Branch, Victoria, B.C.</p> <p>2 - Somewhat Relevant to Jackson WHMP</p> <p>Guidelines based on studies conducted in the dry, pine dominated Montane Spruce zone of eastern BC (Okanagan).</p> <p>The document has three parts:</p> <ol style="list-style-type: none"> 1. Minimum habitat requirements for maintaining marten in the Montane Spruce and dry, pine dominated Englemann Spruce Sub-alpine fir zones. 2. Timber harvest guidelines for maintaining marten habitat at the landscape level within this forest type. 3. Site-specific silvicultural guidelines for maintain marten habitat following timber harvest within this forest type. <p>Summary tables from each part are attached to this citation.</p> <p>Silvicultural Guidelines:</p> <p>CWD is the single most important attribute selected by marten. Salve the largest diameter CWD on the stand, uniformly distributed through the unit. Both sound and decayed CWD</p>

	<p>should be saved. Pile logging debris as a supplement.</p> <p>Wildlife trees must be at least 30 cm dbh and 3 m or more in height. Live trees with cavities, snags and tall hollow stumps are used.</p>
59	<p>B.C. Ministry of Forests. 1996. Coastal Black-tailed deer study.</p> <p>2 - Somewhat Relevant to Jackson WHMP</p> <p>A series of 5 pamphlets:</p> <ol style="list-style-type: none"> 1. Decoding deer movement patterns 2. Clarifying habitat use 3. How black-tailed deer react to logging in their winter habitat 4. Habitat and predator concerns 5. Habitat assessment and planning
261	<p>Bisson, P.A. et al. 2002. Influence of site and landscape features on vertebrate assemblages in small streams. In: Johnson, A., Haynes, R. eds. Proc. of the wood compatibility initiative workshop. Gen Tech. Rep. PNW- GTR-563. Portland, OR: USDA Forest Service. Pac. NW. Res. Stn.</p> <p>3 - Not Relevant to Jackson WHMP</p> <p>Field study in 62 headwater streams on the Olympic Peninsula. Riparian Ecosystem Management Study (REMS).</p> <p>Site-level features included stream habitat type, channel substrate and riparian forest condition canopy density, % riparian early-seral forest, % riparian mid-seral forest, % riparian late-seral forest). Landscape-level features included forest age (early-, mid-, late-seral), drainage characteristics (drainage density, watershed area), elevation, road density, and landslide frequency.</p> <p>Two major headwater vertebrate groups - fishes (cutthroat trout, torrent sculpin, coast range sculpin and amphibians(tailed frog, Cope's giant salamander, torrent salamander.</p> <p>Stream-dwelling amphibians influenced by riparian and watershed features and less affected by in-stream habitat. Stream-dwelling amphibians negatively affected by timber removal near streams. They preferred streams with late-seral riparian and uplands forests, low road density. Buffers of old-growth trees provided habitat refugia for some spp and were source areas for recolonization.</p> <p>The study did not establish a clear relationship b/n riparian forest characteristics and fish abundance in streams.</p> <p>Relationship b/n forest management and integrity of aquatic and riparian systems is complex, and it would be difficult to tailor management actions at the site level to produce desired changes in small stream-dwelling vertebrates at the population level. Changes in riparian forest at the landscape level, however, may influence populations. E.g., the percentage of a watershed in late-seral forest, the time since the last major disturbance, or road density may be important to aquatic- and riparian-associated vertebrates, but they are insufficient by themselves to explain population changes.</p>
97	<p>Bonar, R.L. 2000. Availability of Pileated Woodpecker Cavities and Use by Other Species. J. Wildl. Manage. 64:52-59.</p> <p>3 - Not Relevant to Jackson WHMP</p> <p>Study conducted in Alberta Canada, in Lodgepole Pine-Engelmann Spruce forests.</p>
186	<p>Bradbury, R.B., R.A. Hill, D.C. Mason, J.D. Wilson et al. 2005. Modeling relationships between birds and vegetation.</p> <p>3 - Not Relevant to Jackson WHMP</p> <p>Study conducted on agricultural land in England.</p>

93	<p>Brandeis, T.J., M. Newton, G.M. Filip and E.C. Cole. 2002. Cavity-Nester Habitat Development in Artificially Made Douglas-fir Snags. J. Wildl. Manage. 66:625-633.</p> <p>1 - Very Relevant to Jackson WHMP</p> <p>This is part of an on-going study in forest land in W. OR among 50- to 55-year old Douglas-fir stands that have previously been thinned to a basal area of 18 to 31sq m/ha. Created snags were Douglas-fir and averaged 42.3cm dbh (range of 28.5-72.7 cm dbh) and average height prior to treatment of 37m. Methods used were girdling at the base, 2 different herbicide applications, topping at the base of the live crown (fully topped) and topping in the middle of the live crown (mid-topped). One year later, a subset of trees within each creation category was inoculated with either a heart-rot or sapwood-rot fungi.</p> <p>Of the two topping methods, approximately 95% of the fully topped and 35% of the mid-topped trees were dead after 4 years.</p> <p>Artificial inoculation did not appear to increase the number of external fruiting bodies on the created snags.</p> <p>The fully- topped trees had the highest levels of small foraging holes, cavities and bark patches removed.</p> <p>Woodpecker activity was not affected by the method of snag creation or inoculation, and intensified over time. The greatest single factor in determining snag suitability for foraging is the length of time the tree has been dead.</p>
236	<p>Brett, T.A. 1997. Habitat Associations of Woodpeckers in Managed Forests of the Southern Oregon Cascades. Corvallis, OR, USA. Oregon State Univ. Master's Thesis; 95p.</p> <p>1 - Very Relevant to Jackson WHMP</p> <p>no PUD copy - available from OSU library.</p> <p>Previous research has shown that woodpeckers select for the tallest and largest snags available in all forest types.</p> <p>Higher nest cavities are believed to reduce predation.</p> <p>Recommend providing for the maintenance of 3 to 11 large (>50cm dbh) tall snags/acre depending on site conditions.</p> <p>Author predicts that Nietro 1985 recommendations are too low to sustain viable populations of cavity nesters and notes that another study shows that a majority of biologist believe that current guidelines for snag management are inadequate to maintain target populations of woodpeckers.</p> <p>For nest trees of all 7 species of cavity nesters present, average nest tree dbh = 79cm.</p> <p>Of 163 nest trees found over the 2 year study, 14% were decay class I, 45% class II, 30% class III, 10% class IV.</p> <p>Red-breasted Sapsucker: Nest trees had mean dbh of 80.5cm (random trees were 42.1 cm). Mean Nest ht = 20.4m mean Tree ht = 27.5m Predicted through logistic regression that for each 10cm increase in dbh, likelihood of use increases 10.5x.</p> <p>Hairy Woodpecker: Mean nest tree dbh = 80.4 cm (random = 42.1cm)</p>

	<p>Mean Nest ht = 18.6m mean Tree ht = 28.0m Predicted through logistic regression that for each 10cm increase in dbh, likelihood of use increases 10.4x. Decay class III snags were 16.4x more likely to be used for nesting than class IV.</p> <p>Northern Flicker: Mean nest tree dbh = 77.7 cm (random = 42.1cm) Mean Nest ht = 14.3m mean Tree ht = 19.7m Predicted through logistic regression that for each 10cm increase in dbh, likelihood of use increases 10.2x.</p> <p>Management emphasis should be placed on maintaining larger snags because they provide more foraging substrate, more available nest cavity potential and remain standing longer.</p> <p>Hairy WP were more associated with class III snags; Flickers and RB Sapsuckers were more associated with snags having broken tops.</p> <p>Habitat edges were chosen more often than random for nest site location. RB sapsuckers chose these areas for more than 33% of nest sites found; flickers (24%) and hairy WP (19%) also used these areas more than random (7%), but to a lesser degree than the sapsucker.</p> <p>Openings and open-canopy forests were found to have greater abundance of woodpecker nests, several past studies have also found that woodpeckers will nest in young regenerating forests if adequate numbers and sizes of snags are present.</p> <p>Landscape analysis revealed that woodpecker nest densities were higher in areas with greater habitat complexity (specifically patch heterogeneity and edge habitat).</p> <p>** Recommends snags greater than 80cm be retained in harvest units. This is the average diameter of nest tree used by the 3 species studied.</p> <p>Providing snags larger than the average is preferable as they provide more suitable habitat over the long run.</p> <p>** Recommends using alternatives techniques over a broad landscape, such as partial and shelterwood cuts. Small 20 to 30 acre patches created over a landscape would create habitat diversity but still maintain the integrity of the forest matrix.</p> <p>Small pockets of armillaria root rot could be preserved (they spread at about 1m/yr) to provide a continuous supply of nesting habitat.</p>
119	<p>Buchanan, J.B. and Swedeen, P. 2005. Final briefing report to the Washington state Forest Practices Board regarding spotted owl status and Forest Practices Rules. WA Dept. Fish and Wildlife. Olympia, WA.</p> <p>3 - Not Relevant to Jackson WHMP Summary of spotted owl status, biology, Forest Practices rules. Landscape-level summary, with discussions of outstanding issues, such as use of management circles vs. landscape management.</p>
290	<p>Bull, E.L., J.J. Akenson, B.J. Betts and T.R. Torgersen 1995. The Interdependence of Wildlife and Old-Growth Forests In: Bradford, P., T. Manning and B. l'Anson eds. Wildlife Tree/ Stand-Level Biodiversity Workshop Proceedings. Victoria, B.C. October 1995. 71-76.</p> <p>1 - Very Relevant to Jackson WHMP Mistletoe brooms are important nest structures for Great Gray and Great Horned Owls, as well</p>

	<p>as American Marten.</p> <p>Pileateds excavate new nests each year, and typically roost in hollow trees.</p> <p>The density of large green trees, canopy height, number of canopy layers and density of hard snags were all positively associated with woodpecker abundance.</p> <p>Vaux's swifts are known to be dependent on large diameter, hollow trees for nesting and roosting.</p> <p>Black bears commonly use hollow trees for denning. These trees averaged 114cm dbh (range 91-160cm) and 19m tall (range 8-30m). Trees with top entries are most commonly used by young bears and females, because they are more secure from predators.</p> <p>Martens regularly use large-diameter snags, logs and live trees as rest sites. 36% of rest sites were in platforms, usually resulting from mistletoe.</p> <p>Cavities made up 23% of rest sites, and hollow logs accounted for 10%.</p> <p>Bat roosts were usually found in snags (67% of roosts). The average dbh was 68 cm and height was 22m. The actual roost site was typically high in the tree, averaging 12m.</p>
136	<p>Bull, E.L., Torgersen, T.R., Blumton, A.K., McKenzie, C.M., Wyland, D.S. 1995. Treatment of an old growth stand and its effects on birds, ants, and large woody debris: A case study. Gen. Tech. Rep. PNW-GTR-353. Portland, OR: USDA Forest Service, Pac. NW. Res. Stn. 12 p.</p> <p>3 - Not Relevant to Jackson WHMP</p> <p>Research conducted in mixed-conifer stands in northeastern Oregon. Purpose of the study was to determine if an old-structure stand with high mortality due to spruce budworm could be altered to accelerate regeneration and reduce fuel loads but still maintain its function as old growth for selected bird species.</p> <p>Small-diameter (<15 in dbh) and dead trees were removed. Downed wood <15 in dbh was removed. All live trees of any size and all dead trees >15 in dbh were retained.</p> <p>Vaux's swifts and pileated woodpeckers continued to use the stand after harvest for nesting and roosting. The number of logs >15 in dbh increased, the number of logs with ants increased, but the percentage of logs with ants decreased. The percentage of logs with ants decreased precipitously during the study period. Pileated foraging on logs decreased in the treated stand.</p> <p>Results include only 1 year of data, and can't be used to make definitive recommendations.</p>
141	<p>Bury, R.B., Corn, P.S. 1991. Sampling methods for amphibians in streams in the Pacific Northwest. Gen. Tech. Rep. PNW-GTR-275. Portland, OR: USDA Forest Service, Pac. NW Res. Stn. 29 p.</p>
56	<p>Carey, A.B. 2003. Biocomplexity and restoration of biodiversity in temperate coniferous forest: inducing spatial heterogeneity with variable-density thinning. <i>Forestry</i>, 76(2): 127-136.</p>
202	<p>Carey, A.B. 1995. Sciurids in Pacific Northwest managed and old-growth forests. <i>Ecol. Appl.</i> 5(3):648-661.</p>
200	<p>Carey, A.B. 2000. Effects of new forest management strategies on squirrel populations. <i>Ecol. Appl.</i> 10(1):248-257.</p>
277	<p>Carey, A.B. 2001. Experimental manipulation of spatial heterogeneity in Douglas-fir forests: effects on</p>

	squirrels. For. Ecol. And Manage. 152:13-30.
54	Carey, A.B. 2002. Response of northern flying squirrels to supplementary dens. Wildl. Soc. Bull. 30(2):547-556.
125	<p>Carey, A.B., Holt, M.M., Horton, S.P., Biswell, B.L. 1991. In: Ruggiero, L. F. et al, editors. Wildlife and Vegetation of Unmanaged Douglas-fir Forests. USDA Forest Service, GTR-PNW-285. pp 123-144.</p> <p>1 - Very Relevant to Jackson WHMP</p> <p>For 9 species of cavity-using birds, 277 nests were located. All species preferred Douglas-fir snags >50cm dbh for nesting. DBH range was 54cm for N pygmy owl to 113cm for red-breasted sapsucker, with the mean being 94cm.</p> <p>Abundance and diversity of cavity-using birds was directly correlated with large snags.</p> <p>"Large, and especially very large, moderately decayed snags are of major importance to cavity-using birds."</p> <p>Large snags were selected in greater proportions than their availability, even though small snags (<50 cm) were abundant.</p>
52	<p>Carey, A.B., Johnson, M.L.. 1995. Small mammals in managed, naturally young, and old-growth forests. Ecol. Applic. 5(2):336-352.</p> <p>Compared small mammal communities in natural old-growth stands to managed even-aged and uneven-aged stands in Olympic Peninsula. While small mammal abundance and productivity for most species were greatest in natural old-growth, all spp abundance in managed stands as well. Abundance of small mammals in uneven-aged managed stands tended to be intermediate between natural old-growth and young even-aged stands.</p> <p>CWD and understory shrub layer key variables affecting small mammal abundance. Could be maintained or enhanced by partial cutting.</p>
272	Carey, A.B., Wilson, S.M. 2001. Induced spatial heterogeneity in forest canopies: responses of small mammals. J. Wildl. Manage. 65(4):1014-1027.
278	Carey, A.B., Wilson, T.M., Maguire, C.C., Biswell, B.L. 1997. Dens of northern flying squirrels in the Pacific Northwest. J. Wildl. Manage. 62(3):684-699.
258	<p>Chambers, C.L., McComb, W.C. 1997. Effects of silvicultural treatments on wintering bird communities in the Oregon Coast Range. NW Science 71(4):298-304.</p> <p>2 - Somewhat Relevant to Jackson WHMP</p>
300	<p>Chambers, C.L., McComb, W.C., Tappeiner II, J.C. 1999. Breeding bird responses to three silvicultural treatments in the Oregon Coast Range. Ecol. Appl. 4(1):171-185.</p> <p>2 - Somewhat Relevant to Jackson WHMP</p> <p>Field study assessed bird response to 3 silvicultural treatments in 80-120 yo Douglas-fir/grand fir stands:</p> <ul style="list-style-type: none"> **small-patch group selection treatment representing low-intensity disturbance. 33% of volume removed in 0.2 ha patches **two-story treatment, representing moderate to high-intensity disturbance. 75% of volume removed, retaining 20-30 tph scattered uniformly throughout stand **modified clearcut. 1.2 green trees/ha retained. **control stands <p>Bird species composition in small-patch group selection most similar to control stands. Two-story treatment was more similar to the modified clearcut treatment.</p>

	<p>10 bird spp remained abundant following small-patch group selection treatment. They declined in abundance in modified clearcuts and two-story treatment. The species included 4 neotropical migrant species and 5 spp with restricted geographic ranges and habitat associations.</p> <p>9 spp increased in response to moderate and/or high-intensity disturbances, including a larger proportion of species that were habitat generalists.</p> <p>Low- intensity disturbances most effective in retaining bird spp associated with mature forest. High-intensity disturbances (two-story and modified clearcut) greatly altered bird community composition.</p>
95	<p>Chambers, C.L., T. Carrigan, T.E. Sabin, J. Tappeiner, and W.C. McComb. 1997. Use of Artificially Created Douglas-fir Snags by Cavity-Nesting Birds. W. J. Appl. For. 12:93-97.</p> <p>1 - Very Relevant to Jackson WHMP</p> <p>Snags were created by topping either scattered or clumped live Douglas-fir trees with chainsaws. These averaged 3.8/ha, 17m tall and 75cm dbh. Three stand types were manipulated: modified clearcuts, two-story stands and small-patch group-selection stands.</p> <p>After treatment, cavities were found more often in the two-story and modified clearcuts than the small-patch stands. Snag pattern (clumped vs. scattered) did not affect bird use. Snags were used within 5 years of creation, and secondary cavity nesters were also found, indicating that nest sites were available within a short time period following topping.</p> <p>Hardwoods also provide important nesting opportunities. Big leaf maple (33.0 to 41.7cm dbh, 14.3m ht) was the most common to hold cavities.</p> <p>Clumping of snags may reduce bird densities if clumps are not adequately spaced, due to territoriality.</p>
253	<p>Christy, R.E., West, S.D. 1993. Biology of bats in Douglas-fir forests. Gen. Tech. Rep. PNW-GTR-308. Pac. NW Res. Stn. USDA Forest Service. 28 p.</p> <p>3 - Not Relevant to Jackson WHMP</p>
161	<p>Conner, R. N., S.D. Jones & G. D. Jones. 1994. Snag condition and woodpecker foraging ecology in a bottomland hardwood forest. Wilson Bul. 106: 242-257.</p> <p>3 - Not Relevant to Jackson WHMP</p> <p>Study area is in Texas.</p>
160	<p>Corn, J.G., Raphael, M.G. 1992. Habitat characteristics of marten subnivean access sites. J. Wildl. Manage. 56:442-448.</p> <p>3 - Not Relevant to Jackson WHMP</p> <p>Describes the importance of snags, stumps and logs in providing denning habitat in the central Rocky Mountains.</p>
142	<p>Corn, P.S., Bury, R.B. 1990. Sampling Methods for terrestrial amphibians and reptiles. Gen. Tech. Rep. PNW-GTR-256. Portland, OR: USDA Forest Service, Pac. NW Res. Stn. 34 p.</p>
191	<p>Creighton, J.H. 2000. Controlling black bear damage to conifer stands: does the supplemental feeding program work? Forest Stewardship Notes 9(2):9-10.</p>
147	<p>Davis, J.B., R.M. Kaminski and S.E. Stephens. 1998. Wood Duck Eggshell Membranes Predict Duckling Numbers. Wildl. Soc. Bul. 26:299-301.</p> <p>2 - Somewhat Relevant to Jackson WHMP</p>

	During nest box checks, membranes counted ≤ 5 days post-hatch provided an accurate estimate of number of ducklings; add 1 to this count to derive the most accurate count of hatchlings.
21	DNR. 1997. Final Habitat Conservation Plan. Washington Department of Natural Resources, Olympia, WA. Paging various.
40	<p>Duncan, S. Coming home to roost: The pileated woodpecker as ecosystem engineer. Science Findings 57. October 2003.</p> <p>1 - Very Relevant to Jackson WHMP</p> <p>Summary article based on interviews with Keith Aubry and Catherine Raley from the PNW Research Station, USDA Forest Service, Olympia, WA.</p> <p>Within the range of the N. spotted owl, pileated woodpeckers were found to nest in live, decadent trees equally as often as they do in snags and to use different tree species with different decay characteristics for roosting versus nesting.</p> <p>Nest cavities have single large entrances (usually 21cm wide x 51cm deep). New nest cavities are excavated each year with diameter, height, decay characteristics and surrounding habitat conditions being important factors.</p> <p>Converse to other woodpecker species in the PNW, Pileateds select nest trees that are in the early stages of heartwood decay and that have relatively sound wood.</p> <p>Pileateds show a strong preference for decadent trees for nesting, based on the high proportion of use versus their extremely low density in most forests. Decadent trees are considered to be MORE IMPORTANT for nesting by Pileateds than snags.</p> <p>Nest trees differed in both size and decay characteristics from roost trees. Nest trees typically had only early stages of heartwood rot. Roost trees were typically in trees that had advanced heart rot that had created large natural hollows and had both natural and excavated openings.</p> <p>Silver fir was preferred as a nest tree, but cedar was preferred as a roost tree and not used for nesting.</p> <p>A pair of Pileateds uses only 1 nest tree each year, but each bird used an average 7 or more different roost trees in a year.</p> <p>Decadent trees may be easier to leave within harvest units because they pose significantly less safety risk and will also provide habitat for Pileateds longer than a snag will.</p> <p>Mgmt Recommendation: Standing dead wood in west side forests should be given more consideration because Pileateds were rarely noted to forage on logs, since they likely become too wet to support carpenter ant colonies unless suspended above the forest floor.</p> <p>Nest trees differ from roost trees in both size and decay characteristics. Nest cavities are typically in trees where the heartwood is only partially softened and is still in the early stages of decay. But roost cavities are typically large natural hollows caused by the late stages of heartwood decay and may have both natural and excavated openings.</p> <p>Pacific silver fir was a preferred nesting species, but cedar was preferred for roosting and not used for nesting.</p>
233	<p>Everett, K. T. and K. A. Otter. 2004. Presence of cavities in snags retained in forest cutblocks: do management policies promote species retention? Can. Field. Nat. 118: 354-359.</p> <p>1 - Very Relevant to Jackson WHMP</p>

	<p>Availability of nest sites often limits the population of cavity nesters.</p> <p>Some timber companies retain hardwoods and advanced regeneration trees within cutting units to increase structural diversity after harvest. This helps to reduce the distance that wildlife must travel through an open cutting unit.</p> <p>Forest dwelling species have been shown in several studies to be reluctant to cross gaps between fragmented forests:</p> <ul style="list-style-type: none"> ** forest birds were 3x less likely to cross gaps 70 m wide, and 8x less likely to cross gaps 100m wide versus similar distances in the forest. ** snags retained within the cutting unit may be less utilized simply because of the reluctance to cross open gaps from the forest edge. ** distance from forest edge had a inverse relationship on the frequency of cavities. **cavities were more common within the forest than the cut unit. **snags located farther from forest cover were underutilized. <p>Cavity nesters preferred deciduous trees for nesting, thus a high component of these trees should be maintained for the purpose of managing cavity nesting birds.</p> <p>***Highest density of cavities was within 100m of the edge.</p> <p>Class 2 & 3 snags have been found to have higher nesting success by primary cavity nesters.</p>
188	<p>Gibbs, J.P., M. L. Hunter, Jr., and S. M. Melvin. 1993. Snag Availability and Communities of Cavity Nesting Birds in Tropical Versus Temperate Forests. <i>Biotropica</i> 25:236-241.</p> <p>3 - Not Relevant to Jackson WHMP</p> <p>Simply compares availability of snags in tropical and sub tropical areas to temperate systems.</p>
292	<p>Gitzen, R.A. 1999. The Effects of Experimental Canopy Gaps on Small Mammal Communities in the Southern WA Cascades. Seattle, WA. Univ. of WA, Master's thesis. 125p.</p> <p>1 - Very Relevant to Jackson WHMP</p> <p>Thesis available at UW Library</p> <p>Leaving small gaps during planting and creating small openings during thinnings may promote understory development.</p> <p>Gaps ranged from 1/1000th acre (0.004 ha) to 1/2 ac (0.20ha) and were 5-7 years old, with some 1 ha gaps from a concurrent study also examined. The small gaps are roughly equal to a single tree death. Gap sizes were relative to the canopy height. 1.0 gaps would be approx 50m diam in mature & old stands, and 35m in young stands.</p> <p>Stand age: 90yo = young, 140yo = mature, 500yo = old.</p> <p>Gaps increased low vegetation cover, but had not effect on tall shrubs and CWD.</p> <p>Only 1 species of small mammal (<i>Microtus oregoni</i>) showed a strong response to the gaps in terms of occurrence. <i>Sorex</i> spp. Trended toward lower abundance, possibly as a result of disturbance and soil compaction during mechanical gap creation.</p> <p>Lack of strong association between small mammals and gaps may be a result of territory size. The 0.2, 0.4 gaps in all stands and the & 0.6 gaps in young stands cover only a portion of the average home range size of many forest dwelling small mammals.</p> <p>Given the low sun angles in the Northwest, the relation of opening size to canopy height may be more important than actual gap size in determining vegetation response.</p>

	<p>If gaps fill in with hemlock or silver fir, resources required by small mammals may actually decrease.</p> <p>Forest gaps appear to increase resources for forest species, as opposed to recruiting early-successional species.</p> <p>Creation of gaps 30 to 50m in diameter may serve to increase populations of small mammals which in turn feed weasels and marten, but the small mammals may also affect seedlings survival.</p> <p>Shrub and herb production gaps may actually decrease in gaps if they fill in with hemlock or silver fir.</p>
171	<p>Gitzen, R.A. and S. D. West. 2002. Small Mammal response to Experimental Canopy Gaps in the Southern Washington Cascades. <i>For. Ecol. And Manage.</i> 168:187-199.</p> <p>1 - Very Relevant to Jackson WHMP</p> <p>Gap sizes were created relative to the height of the overstory trees.</p> <p>Gaps that were 1.0 relative to canopy height in mature and old-growth stands were approximately 0.4 ac in size.</p> <p>Most closed-canopy species in western Washington are present after large-scale disturbances, and it appears that sharp changes in occurrence or abundance are unlikely in these small openings. The large gaps were roughly the size of only one to two home ranges for the small shrews, <i>Peromyscus</i>, and the southern red-backed vole.</p> <p>When such openings affect species composition, they frequently have done so by attracting early-successional specialists rather than by excluding forest species. Abundances of closed-canopy species generally have been similar or higher in openings than in forest controls.</p> <p>Due to aggressive responses by western hemlock and slow colonization and growth by <i>Vaccinium</i>, small disturbances in southeast Alaska coastal forests may actually decrease understory shrub and herb cover. In the western Cascades, gaps sometimes may be filled with dense regeneration of western hemlock or Pacific silver fir, potentially decreasing ground-level cover.</p> <p>For small mammals, most individual gaps probably have minor effects on abundances and no effects on species occurrence in the southern Washington Cascades. The extremely tall, narrow-crowned trees and low sun angle of the Pacific Northwest result in relatively subtle effects of small treefall gaps compared to dramatic changes associated with single-tree gaps in some tropical forests (Spies et al., 1990).</p> <p>Based on evidence from this study, creation of multiple small gaps in mature stands seems more likely to increase rather than decrease abundances of the relatively flexible closed-canopy species in western Washington.</p> <p>In forests similar to these sites, relatively large gaps or a large number of small gaps may be needed to increase species diversity by providing habitat for early-successional small mammals.</p>
198	<p>Grialou, J.A., West, S.D., Wilkins, R.N. 1999. The effects of forest clearcut harvesting and thinning on terrestrial salamanders. <i>J. Wildl. Manage.</i> 64(1):105-113.</p> <p>Field study of short-term effects of clearcut and thinning on terrestrial salamanders in sw WA.</p>

	<p>Population responses of salamander species to forest management are variable, with some species declined after harvest.</p> <p>Western red-backed salamanders, ensatinas, northwestern salamanders, rough-skinned newts, and Dunn's salamanders were captured in both forested and clearcut areas. Columbia torrent salamanders and Pacific giant salamanders were captured only in forested areas. Capture rates of red-backed salamanders were greater in forested than clearcut areas, and individuals were smaller in the clearcut areas. This species declined after thinning. Ensatina showed no different in capture rate in the first post-harvest year, but decreased in clearcuts in the second year.</p>
121	<p>Gyug, L.W. 1993. Furbearer and prey use of logging debris piles in clearcuts: progress report 1992/3. Consultant report prepared for Ministry of Environment, Penticton.</p> <p>3 - Not Relevant to Jackson WHMP</p> <p>Study area was interior southern BC. Report motivated by concern that burning of logging debris might lead to long-term habitat losses for marten.</p> <p>Marten and weasels use young clearcuts with high levels of logging debris (>1 spot-pile/ha or >1 roadside-logging windrow per block) more than clearcuts with no debris piles or low levels of piles. Marten prefer the longer windrow piles resulting from roadside logging.</p> <p>Snowshoe hare, yellow-pine chipmunk, deer mouse and lynx use of these young clearcuts not affected by retention of logging debris piles. Red squirrels and red-backed voles (a favorite prey of marten and weasels) did not use young clearcuts.</p>
190	<p>Gyug, L.W. and S.P. Bennett. 1995. Bird Use of Wildlife Tree Patches 25 Years After Clearcutting. In: Bradford, P., T. Manning and B. l'Anson eds. Wildlife Tree/ Stand-Level Biodiversity Workshop Proceedings. Victoria, B.C. October 1995. 15-33.</p> <p>1 - Very Relevant to Jackson WHMP</p> <p>Study conducted in South-Central B.C.</p> <p>Wildlife tree patches were designated as "no-work" zones where snags did not have to be felled for worker safety.</p> <p>In one harvest area, 7% of the 160 ha harvest area was reserved in 12 seed tree patches, with a mean patch size of 0.9 ha (range 0.3 - 1.5 ha); mean inter-patch distance to neighbor was 203m.</p> <p>In another harvest area or 1000 ha, 29 seed tree patches were left (10% of harvest area). Mean patch size was 3.6 ha (range 1.6 - 18.9 ha). Mean distance between patches was 201m. Most patches were small (median 2.3 ha).</p> <p>Owls and woodpeckers were sampled in the harvest units 25 to 29 years post-harvest. No species of either were detected in clearcuts, some were found in forest patches, and all were found in the neighboring forest.</p> <p>The Pileated was absent from the patch areas and clearcuts.</p> <p>Hairy woodpecker, Northern flicker and red-naped sapsucker were found in the patch environments.</p> <p>Tree species, diameter and decay class were much more significant in determining woodpecker use of individual wildlife trees than the habitat.</p> <p>A majority of nests were found in snags greater than 75 cm dbh.</p>

	<p>Authors felt that wildlife tree patches were quite effective at mitigating the effects of clearcutting on many species.</p> <p>Only one cavity-nesting bird was found in the harvest units without reserve patches.</p>
128	<p>Hagar, J.C., McComb, W.C., Emmingham, W.H. 1996. Bird communities in commercially thinned and unthinned Douglas-fir stands of western Oregon. <i>Wildl. Soc. Bull</i> 24(2):353-366.</p> <p>2 - Somewhat Relevant to Jackson WHMP</p> <p>Study compared abundance and diversity of breeding and winter birds between commercially thinned and unthinned second-growth Douglas-fir stands in the Oregon Coast Ranges.</p> <p>64 habitat variables sampled or derived from data: e.g. distance to streams, distance to patch edge, patch size, height and diameter of tree layer, basal area of conifers, hardwood, snags, snag size, woody vegetation height, percent shrub and tree cover, and others.</p> <p>Abundance of many breeding birds consistently greater in thinned stands: (Hammonds's flycatchers, hairy woodpeckers, red-breasted nuthatches, dark-eyed juncos, warbling vireos and evening grosbeaks)</p> <p>Abundance of few other species consistently greater in unthinned stands (Pacific-slope flycatchers).</p> <p>Some species were inconsistent in thinned or unthinned stands between seasons, years, or regions (brown creeper, western tanager, winter wren, golden-crowned kinglets, gray jays, black-throated gray warblers, and others).</p> <p>Bird species richness correlated with structural features: habitat patchiness and densities of hardwoods, snags and conifers. In general, enhance structural features associated with richness by increasing size and abundance of hardwoods, conifers and snags, and providing shrub cover.</p> <p>Management recommendations: Commercial thinning for Hammond's flycatchers, western tanagers because these species have declined in abundance.</p> <p>Commercial thinning plus create snags and release hardwoods for other species in decline: chestnut-backed chickadees, warbling vireos, black-throated gray warblers.</p> <p>Thin from below for species associated with old, unmanaged forests (e.g. Hammond's flycatcher, red-breasted nuthatch). Recommended relative density between 0.2 and 0.3, (i.e. only short periods of crown closure allowed). Development of shrub cover associated with Wilson's warblers, Swainson's thrushes and warbling vireos. Low tree stem density may favor Hammond' flycatchers, hairy woodpeckers, and dark-eyed juncos.</p> <p>Higher relative densities of trees (>4.0+) benefits golden-crowned kinglets and Pacific-slope flycatchers. Black-throated gray warblers may benefit from denser stands if hardwoods also present. (Note: competition mortality of tree layer was found at RD>0.55)</p> <p>Recommend variable densities across a stand (0.2 - 0.7) for bird species richness, as follows: unthinned strips or patches (approx. 8ha per 40 ha of thinning, to include birds' territories, could be left adjacent or within thinned stands.</p>
267	<p>Hansen, A.J., McComb, W.C., Vega, R., Raphael, M.G., Hunter, M. 1995. Bird habitat relationships in natural and managed forests in the west Cascades of Oregon. <i>Ecol. Appl.</i> 5(3):555-569.</p> <p>3 - Not Relevant to Jackson WHMP</p> <p>Bird abundance data from several studies.</p>

	<p>Most forest birds can be placed in 4 guilds in terms of overstory tree canopy use:</p> <ul style="list-style-type: none"> **open canopy spp (dark-eyed junco, american robin) **open canopy with dispersed large trees (MacGillivray's warbler, Hammond's flycatcher, western tanager) **structurally complex closed-canopy (brown creeper, chestnut-backed chickadee, winter wren) **structurally simple closed-canopy (golden-crowned kinglet, Swainson's thrush)
89	<p>Harestad, A.S. and Keisker, D.G. 1989. Nest tree use by primary Cavity-nesting birds in South Central British Columbia. <i>Can. J. Zool.</i> 67:1067-1073.</p> <p>2 - Somewhat Relevant to Jackson WHMP</p> <p>Biogeoclimatic zone appears to be significantly different than our area. Nest trees were primarily Trembling Aspen and Paper Birch. Douglas fir and Hybrid Spruce were available but not used. This does, however, point to the need to preserve hardwoods wherever available for nesting & roosting opportunities.</p>
166	<p>Hargis, C.D., McCullough, D.R. 1984. Winter diet and habitat selection of marten in Yosemite National Park. <i>J. Wildl. Manage.</i> 48:140-146.</p> <p>2 - Somewhat Relevant to Jackson WHMP</p> <p>California study results</p> <p>Recommendation: "The impact of clear-cutting may be reduced by leaving clusters of trees spaced no farther than 50 m apart. Logs and slash should be left for foraging sites, winter dens and subnivean travel routes."</p>
293	<p>Hartwig, C.L. 1999. Effect of Forest Age, Structural Elements, and Prey Density on the Relative Abundance of Pileated Woodpecker (<i>Dryocopus pileatus</i>) on Southeastern Vancouver Island. Victoria, British Columbia, Canada. Univ. of Victoria. Master's Thesis.</p> <p>1 - Very Relevant to Jackson WHMP</p> <p>Copy available on microfiche from U of Victoria.</p> <p>Relative abundance of PWP was not significantly different in landscapes with 51% of >140 yo stands (greatest rel. ab.); in forests with 49% >80yo; or forest with 70% >140 yo.</p> <p>Snags & decadents used for foraging were larger (56cm dbh mean), more decayed, less bark (49% mean) and were in the upper and main canopy strata versus those not used for foraging.</p> <p>Foraging areas also had mean CWD of 192 +/- 26 SE cubic meters/ha. Logs used for foraging were larger, longer and less decayed than those not used.</p> <p>Cedar was also more common in areas used for foraging.</p> <p>Mean ht of cavities was 22 +/- 5.2 SE m</p> <p>Nesting trees mean dbh = 82 +/- 16 SE cm, mean ht 22 +/- 5.2 SE m, and 91% +/- 9 SE bark remaining.</p> <p>Nest and roost sites had significantly greater basal area of snags and defectives (mean 7.6 (+/- 1.0) sq m/ha).</p> <p>Study area SE Vanc Island</p> <p>Calls were most frequently heard within 1 hour after sunrise, and decreased for 5 hours, then began to rise again slightly.</p> <p>Snags > 45-57.49 cm and > 57.49 were used more than available.</p> <p>Neither CWD or snag mean sizes or preferred sizes were <38cm for snags and <25 cm for</p>

	<p>CWD.</p> <p>Cedar and alder were selected for by PWP.</p> <p>Douglas fir and maple were used in proportion to availability.</p> <p>An average of 7 different roost trees are used by each bird in a 3 to 10 month period.</p> <p>Habitat at nest plots had significantly more basal area, older structural stage, older successional stage, & less disturbance than habitat at unused sites.</p> <p>Nest and roost trees were significantly larger and taller than most other trees.</p> <p>Of studies reviewed for this manuscript, the NW WA cascades reported the largest mean nest tree sizes (100.5 cm dbh) Aubry & Raley 1995.</p> <p>This is likely due to more moisture leading to better growing conditions.</p> <p>Nest trees in WA were the tallest (39.5m) widest (100.5 cm dbh) and had the highest nests (35.2m) of all N Am studies.</p> <p>Areas with forest >80 yo, high snag densities, high CWD volumes had higher prey densities for PWP and higher abundance of PWP.</p> <p>An inadequate supply of nest snags for PWP may result in them re-using the same tree in subsequent years, thereby reducing the number of cavities available for secondary cavity nesters.</p> <p>Research focused on the highest densities or on optimum suitability have recommended higher snag numbers (30-50/ha),</p> <p>Basal area of snags (>20 dbh) in foraging areas was 7.5 (+/- 1.1 SE) sq m/ ha; roughly equal to 28 snags of 56cm dbh/ha.</p> <p>Recommends leaving snags in moderately dense clumps, not evenly distributed across the landscape.</p>
16	<p>Hartwig, C.L., D.S. Eastman and A.S. Harestad. 2002. Forest age and relative abundance of pileated woodpeckers on southeastern Vancouver Island. In: Laudenslayer, W.F. et al. eds. Proc. Of the Symposium on the Ecology and Management of Dead Wood in Western Forests. PSW-GTR-181. pp. 247-256.</p> <p>2 - Somewhat Relevant to Jackson WHMP</p> <p>PWP did not use managed forests <80 years old that had low densities of large snags & logs.</p>
168	<p>Hartwig, C.L., D.S. Eastman and A.S. Harestad. 2003. Characteristics of Pileated Woodpecker (<i>Dryocopus pileatus</i>) Cavity Trees and Their Patches on Southeastern Vancouver Island, BC, Canada. For. Ecol. And Manage. 187:225-234.</p> <p>1 - Very Relevant to Jackson WHMP</p> <p>Nest trees are considered the limiting factor for most populations of pileated woodpeckers (Bull and Jackson, 1995), and so in managed forests, there is a need to ensure that these trees are not removed during timber harvesting and other forestry activities.</p> <p>Cavity trees were significantly larger in diameter (78 +/- 6 cm) than trees without cavities (47 +/- 2 cm). As well, they were taller and comprised a larger proportion of the trees in the upper canopy and above canopy classes.</p> <p>Western hemlock had less canopy cover in cavity patches, while big leaf maple and grand fir</p>

	<p>had greater canopy coverage. No significant differences in cover were found for Douglas-fir, western red cedar and red alder.</p> <p>PWP habitat patches with cavity trees had slightly fewer Hemlock, but significantly more big leaf maple and grand fir.</p> <p>Of the major studies of pileated woodpecker, the Cascade Mountains of northwestern Washington had the largest mean dbh of nest trees at 100 cm (Aubrey and Raley, 1995). This likely reflects the availability of large trees at their site which were, on average, larger than those in our study area. Harestad and Keisker (1989) reported the smallest mean dbh of any North American study at 40.5 cm in southcentral British Columbia. This small size of nest trees likely reflects the relatively small size of trees available in their study area.</p> <p>The broad range in diameters of trees used by pileated woodpeckers for nesting indicates flexibility in nest tree selection. However, in all published studies, pileated woodpeckers select the larger trees of those available and thus reveal a consistent preference for large-diameter trees for nesting. Such preference probably relates to their need for suitably sized nest chambers in which to raise young.</p> <p>Nest trees in western Washington were the tallest (40 m) and had the highest nests (35 m).</p> <p>Nest trees are less likely to occur in clear cut or patch-retention treatments (Gyug and Bennett, 1995).</p> <p>In addition to retaining suitable large trees, it is important to reserve stands with a greater proportion of big leaf maple and grand fir (and less western hemlock), in mature or older structural stages and mature climax successional stages.</p>
225	<p>Hartwig, C.L., Eastman, D.S., Harestad, A.S. 2006. Characteristics of foraging sites and the use of structural elements by the pileated woodpecker (<i>Dryocopus pileatus</i>) on southeastern Vancouver Island, British Columbia, Canada. <i>Ann. Zool. Fennici</i> 43:186-197.</p> <p>1 - Very Relevant to Jackson WHMP</p> <p>Until recently, feeding habitat had not been considered as important as nesting habitat for PWP because any woody debris >18 cm was considered available for feeding year round.</p> <p>Additional research points to selection for much larger trees than previously thought in many areas, including WA.</p> <p>Snags and defective trees used for foraging were larger, more decayed, and had significantly less bark and fewer limbs than those not used.</p> <p>Used snags and defectives were significantly larger in mean dbh than unused ones. The numbers of snags used in the two largest dbh classes were significantly greater than those in all other classes of snags and defectives that were used.</p>
80	<p>Hayes, J.P., Chan, S.S., Emmingham, W.H. (and others). 1997. Wildlife response to thinning young forests in the Pacific Northwest. <i>J. Forestry</i> 95(8):28-33.</p> <p>2 - Somewhat Relevant to Jackson WHMP</p> <p>Review article on enhancing stand structure in second growth stands.</p> <p>---Promote large live trees. Thinning results in increased diameter growth</p> <p>-- Promote large crowns to provide better habitat for birds, red tree voles.</p> <p>---Thinning in 20- to 50-year-old stands promotes development of large crowns on dominant and codom trees if done relatively early in a stand's development. See Marshall 1992.</p> <p>---Promote large branches. They develop only on widely spaced trees or on trees adjacent to gaps or openings.</p>

	<p>---Deep fissures in the bark, typical of large-diameter Douglas fir. No silvicultural techniques available to accomplish this, but could create desirable habitat.</p> <p>---Promote large snags and down trees. No numbers provided</p> <p>---Multilayered canopies. No specifics</p> <p>---Understory vegetation. Response of understory veg to thinning depends on initial density, species composition, vigor of understory plants before thinning, seed sources and bud banks, thinning intensity, soil disturbance; however, sunlight is the primary factor. Thinning to moderate densities in closed-canopy stands stimulates modest and temporary development of understory veg (e.g. RD 25); heavier thinning or multiple entries favors the establishment and growth of conifer seedlings, shrubs and hardwoods (e.g. RD 20).</p> <p>Timing: Thinning stands before age 15 will encourage wind firmness and large crowns. Thinning dense stands in the stem exclusion stage increases potential for windthrow, although thinning in stages can minimize the problem. Repeated thinning in later stages (age 70 to 100) may lead to stands resembling shelterwood, with understory beneath a few large trees.</p> <p>Relative Density: The actual density of trees relative to the theoretical maximum density possible for the site, on a scale of 0 to 100.</p> <p>At RD>55m suppression mortality happens</p> <p>Stands typically thinned to RD 35 for timber production, and allowed to grow back to RD 55 before final harvest or additional thinning.</p> <p>Thinning to >RD 35 is a light thinning.</p> <p>Thinning to RD 25 or less (heavy thinning) and thinning again when the stand grows to RD 45 promotes understory development and vertical diversity.</p> <p>RD diagram (see supportive link) predicts stands can have about 20 healthy, 50-inch dbh trees per acre; stands at this density are likely to have a rich understory. Stands with 40 50-inch dbh douglas-fir trees per acre are likely to be in poor condition and have little understory; trees at this density will also attain that size relatively slowly. Need empirical evidence to confirm this.</p>
286	<p>Hayes, J.P., Weikel, J.M., Huso, M.M. 2003. Response of birds to thinning young Douglas-fir forests. <i>Ecol. Appl.</i> 13(5):1222-1232.</p> <p>1 - Very Relevant to Jackson WHMP</p> <p>Breeding bird surveys before and five years after thinning stands in western Oregon. 22 species analyzed in this paper. Treatments on 35-45 y.o. Douglas-fir stands:</p> <p>Control = no thinning</p> <p>moderate thinning = relative density of 35, or 240-320 tph</p> <p>heavy thinning = relative density of 20, or 180-22- tph</p> <p>Results: Response of birds to thinning was generally rapid, with patterns for most spp evidence during the 1st yr after thinning. Patterns of response for most spp relatively consistent across years; marked temporal patterns not common.</p> <p>Hutton's vireo and brown creeper - negative response to intensity of thinning</p> <p>Hermit warbler, golden-crowned kinglet, Swainson's thrush, black-throated gray warbler also decreased on thinned stands, but no change relative to thinning intensity.</p> <p>Stellar's jay and varied thrush decreased only in heavily thinned stands.</p> <p>No change: gray jay, chestnut-backed chickadee, winter wren, Wilson's warbler, red-breasted nuthatch</p> <p>Dark-eyed junco and hairy woodpecker increased in moderately thinned and even more in heavily thinned stands. Warbling vireo increased only in heavily thinned stands.</p> <p>American robin, Townsend's solitaire, evening grosbeaks, western tanagers and Hammond's flycatcher all increased in thinned stand but no difference relative to thinning intensity. The solitaire and flycatcher never observed in control stands.</p> <p>Management recommendations: Thinning densely stocked conifer stands in landscapes</p>

	<p>dominated by younger stands enhances habitat suitability for several bird spp, (consistent with findings of Hagar et al 1996, Haveri and Carey 2000), but some unthinned patches (<0.5 ha) and stands should be retained to provide refugia for species that are impacted by thinning. Suggests variable-density thinning with retention of legacy structures and dead wood.</p> <p>Caveats: Results may not be applicable to much more intensive treatments, e.g. shelterwood. Results were 1st 6 yrs post-thinning: response of birds >10 yrs post-thinning need to be studied. Did not study influence of thinning on reproduction or survival, possibly more important indicators of habitat quality than abundance. Possible influence of different adjacent habitats despite generous size of stands (25 - 40 ha).</p> <p>Generalities: Strongest inference can be applied to forests of similar structure in the same region. However, since findings consistent with known natural history of these spp, likely their results applicable to same spp in other coniferous forests of similar structure.</p>
132	<p>Hayes, M.P, Jennings, M.R. 1986. Decline of ranid frog species in western North America: are bullfrogs (<i>Rana catesbeiana</i>) responsible? <i>J. Herpetol.</i> 20(4):490-509.</p> <p>Predation by both bullfrog and introduced fishes supported by this review; fish predation may be more significant.</p>
144	<p>Hepp, G. R. and R. A. Kenner. 1992. Characteristics and Consequences of Nest-Site Fidelity in Wood Ducks. <i>Auk</i> 109:812-818.</p> <p>2 - Somewhat Relevant to Jackson WHMP</p> <p>Individual cavity-nesting ducks that are successful are more likely to return to the same nest site than those that are unsuccessful.</p> <p>Those females that used the same box in subsequent years also began nesting earlier (13 days) and had larger clutches than those that returned to the same wetland, but chose a different box than the prior year.</p> <p>Buffleheads tended to show greater nest site fidelity than wood ducks or common Goldeneyes.</p>
126	<p>Huff, M.H., D.A. Manuwal, and J.A. Putera. 1991. In: Ruggiero, L. F. et al, editors. <i>Wildlife and Vegetation of Unmanaged Douglas-fir Forests</i>. USDA Forest Service, GTR-PNW-285. pp 207-218.</p> <p>1 - Very Relevant to Jackson WHMP</p> <p>see supporting link</p>
279	<p>Humes, M.L., Hayes, J.P., Collopy, M.W. 1999. Bat activity in thinned, unthinned, and old-growth forests in western Oregon. <i>J. Wildl. Manage.</i>, 63(2):553-561.</p>
155	<p>Hunter, J.E. & M. L. Bond. 2001. <i>Residual Trees: Wildlife Associations and Recommendations</i>.</p> <p>3 - Not Relevant to Jackson WHMP</p> <p>Primarily focuses on retention of residual trees in logging units of coastal southern California/Redwoods area.</p>
243	<p>Irwin, L.L., D.F. Rock and G.P. Miller. 2000. Stand Structures Used by Northern Spotted Owls in Managed Forests. <i>J. Raptor Res.</i> 34: 175-186.</p>
137	<p>Jack, S.B., Parks, C.G., Stober, J.M., Engstrom, R.T. 2003. Inoculating red heart fungus (<i>Phellinus pni</i>) to create nesting habitat for the red-cockaded woodpecker. <i>Proceedings, Red Cockaded Woodpecker Symposium</i>, Jan. 2003, Savannah, GA. 18 p.</p> <p>3 - Not Relevant to Jackson WHMP</p> <p>Study results from sw Georgia involving southern pine species. Initial trial setup described.. Discussion of merits of artificial cavities vs. introduction of red heart fungus into trees. There is evidence that the inoculation process promotes the conversion of sapwood to heartwood</p>

	through the compartmentalization process (see Rayner, A.D.M., , Boddy, L. 1988. Fungal decomposition of wood - its biology and ecology. John Wiley and Sons, New York,. 567 p..
84	Johnson, D.H., O'Neil, T.A., managing dirs. 2001. Wildlife-Habitat Relationships in Oregon and Washington. Corvallis, OR: Oregon St. Univ. Press.
205	Johnston, B., Frid, L. 2002. Clearcut logging restricts the movements of terrestrial Pacific giant salamanders (<i>Dicamptodon tenebrosus</i> Good). Can. J. Zool. 80(12):2170-2177.
150	<p>Jones, L., Holyan, J., Ray, S. 1993. Ecology and management of American martens in fragmented habitats of the Pacific Northwest. Progress Report: Fiscal Year 1993. USDA Forest Service Pacific NW Res. Stn., Forestry Sciences Laboratory, Olympia, WA.</p> <p>Marten used the largest trees in the vicinity as resting sites: Live trees (44%), avg. 92.1 cm dbh and 35.7 m tall Snags (20%), avg. 81.6 cm dbh, 13.9 m tall Slash pile (% unclear)</p> <p>Natal den sites had attributes similar to resting sites: a large live hemlock near a stream is typical.</p>
149	<p>Jones, L.L.C. 1990. Ecology and management of marten in fragmented habitats of the Pacific northwest. Progress Report: Fiscal Year 1991. USDA Forest Service Pacific NW Res. Stn., Forestry Sciences Laboratory, Olympia, WA.</p> <p>The first year of radio-telemetry field work on marten on the white River Ranger District, Mount Baker-Snoqualmie National Forest.</p> <p>Old growth western hemlock/silver fir forest use disproportionately, in proximity to streams or rivers, year-round.</p> <p>Home range size averaged 805 ha for females, 1571 ha for males.</p> <p>Resting sites: Live trees (45%), used in accordance with their availability. Avg. 97 cm dbh, 32.3 m tall for western hemlock, Douglas-fir slightly larger and taller. Live hemlocks had numerous cavities originating as dead branches that had rotten into the bole, or from scars in the bark. Witch's brooms and heart rot cavities, broken-topped trees were occupied by martens</p> <p>Snags (23%) in decay class 4, with most of the bark missing, major branches gone, and soft, or hollow interiors. Avg. 81 cm dbh and 13.3 m tall</p> <p>Log or slash piles (10%)</p> <p>2 natal dens found in large live hemlock trees.</p>
133	<p>Jones, L.L.C. 1991. Ecology and management of marten in fragmented habitats of the Pacific northwest. Progress Report: Fiscal Year 1991. USDA Forest Service Pacific NW Res. Stn., Forestry Sciences Laboratory, Olympia, WA.</p> <p>2 - Somewhat Relevant to Jackson WHMP Study involving radio-telemetry and camera monitoring in western Washington sites.</p> <p>Martens used old growth forests disproportionately, and used clearcuts less frequently than available in their home ranges. (Note, the study area lacked mature second-growth forests, 20 to 80 years old). Martens were usually located near streams.</p> <p>Resting sites included live trees (42%, of which 70% were western hemlock). Snags accounted for 23% of the resting sites. Manmade slash piles accounted for 11%. Large</p>

	<p>canopy trees were used according to their availability, although western hemlock was utilized more than Pacific silver fir. Average dbh of live tree resting sites was 100 cm. Average dbh for snags was 81 cm.</p> <p>Natal dens were similar to typical resting sites: large-diameter live trees (usually western hemlock) or snags, near water.</p>
173	<p>Joy, J.B. 2000. Characteristics of Nest Cavities and Nest trees off the Red-Breasted Sapsucker in Coastal Montane Forests. <i>J. Field Ornithol.</i> 71:525-530. 1 - Very Relevant to Jackson WHMP No nest cavities were reused in the second year</p> <p>Mean DBH of nest trees was significantly greater than that of non-nest trees >17 cm dbh ($t=10.54$, $df=125$, $P<0.001$, Fig. 2.). Mean nest tree height ($\bar{x}=32.5$ m ± 2.4 SE, $n=31$, range 16.8–47.1) was also significantly greater than the mean height of random trees ($\bar{x}=14.75$ m ± 0.81 SE, $n=88$, $t=10.45$, $df=118$, $P<0.001$). The distribution of wildlife tree classes differed significantly from expected ($G=23.95$, $df=6$, $P<0.05$, Fig. 3). Sapsuckers selected only dead trees.</p> <p>Nest height averaged 17.2 m and was positively correlated with tree height ($r=0.55$, $df=30$, $P<0.001$).</p> <p>Red breasted Sapsuckers consistently chose nest trees of larger diameter than non-nest trees, as has been found with other sapsuckers (Dobkin et al. 1995) and other small woodpeckers.</p> <p>Red-breasted Sapsuckers require large nest cavities to accommodate large clutches and up to six nestlings (Campbell et al. 1990).</p> <p>Rates of predation and nest failure decrease among cavity nesters with increasing nest height (Nilsson 1984, Li and Martin 1991).</p>
53	<p>Keisker, D.G. 1986. Nest tree selection by primary cavity-nesting birds in south-central British Columbia. Burnaby, BC. Simon Fraser University. M.S. Thesis. 67p. 3 - Not Relevant to Jackson WHMP Thesis produced in 1987, from south-central BC, where the 3 primary tree species were aspen, birch and alder.</p>
163	<p>Kellam, J. S. 2003. Pair Bond Maintenance in Pileated Woodpeckers at Roost Sites During Autumn. <i>Wilson Bul.</i> 115: 186-192. 3 - Not Relevant to Jackson WHMP Study conducted in Maine.</p>
102	<p>Knutson, K.L. and V. Naef. WDFW, June 1995. SNAGS: Management Recommendations for Washington's Priority Habitats. 137p. 1 - Very Relevant to Jackson WHMP Bernice, this doc has brief mentions of Riparian buffers, CWD, etc.</p> <p>Mike's review: Westside forests containing 4 snags/acre or more that are greater than 20" dbh are considered Priority Habitat.</p> <p>Approx. 102 species in Washington use snags; 56 species nest or den solely in cavities within</p>

	<p>dead or dying trees.</p> <p>*** the following 14 cavity-nesting species are Priority Species, ***** Northern Spotted Owl is listed as endangered; ***** The Pileated WP and Vaux's Swift are both Candidate Species for listing. ***** The remainder are Priority Species, considered for listing: flamulated owl, purple martin, western bluebird, fisher, wood duck, Barrow's Goldeneye, common goldeneye, bufflehead, hooded merganser, marten and western gray squirrel.</p> <p>*** Natural ecosystems should provide the model for determining suitable numbers and characteristics of desired snags, i.e. average density and size found in unmanaged old-growth forests should serve as the targets for snag retention. Diverse, abundant and stable communities of snag-using species occur in unmanaged forests, particularly late-successional stands. Past use of minimums as standards has resulted in less habitat being provided than necessary, and hence continued population declines.</p> <p>Only old-growth stands were found to support 100% of the maximum potential population of primary cavity-nesters, so managing for averages based on these areas provides the best hope of retaining and increasing populations of snag dependent wildlife. Without such measures, the 56 cavity-dependent wildlife species will likely continue to decline in number, and may be listed as threatened or endangered.</p> <p>*** Models (i.e. Thomas et al. 1979) that have been used for the past 15 years have several problems, they only consider nesting requirements, not foraging or roosting and therefore appear to underestimate the number of snags needed.</p> <p>*** Additionally, these models may underestimate by assuming that meeting the needs of primary cavity excavators also meets the needs of other snag dependent species. In fact, secondary users may be more sensitive to snag densities than the primary nesters.</p> <p>Snags should be retained both individually and in clumps (including live trees and existing snags), if possible, and should be well distributed across the landscape. Clumps reflect the natural pattern of trees dying in patches from insects, small fires and disease. Clumping may also help to reduce impacts on logging operations.</p> <p>Artificial snag creation should not take the place of retaining existing snags.</p> <p>Snags in riparian areas are particularly important because several cavity-nesting species (wood duck, osprey, pileated wp) preferentially breed close to streams and wetlands.</p> <p>As a group, cavity-excavators prefer trees greater than 24 m (79ft) tall.</p> <p>Snags in decay stages 2-4 (7-125 yrs old) are most commonly used for nesting. At the start of stage 4 (51 years old) nesting use begins to decrease.</p> <p>Douglas-fir are the most commonly used nesting tree, but are also the most available in larger size classes. They tend to decay from the outside in and are favored by weak excavators. Hemlock are more susceptible to heart rot and are therefore more attractive to woodpeckers, but stand for a shorter period.</p> <p>Hardwoods tend to grow in irregular shapes and can produce cavities in the trunk or branches even while alive. Since they are much less common than conifers, they are particularly valuable wherever they are found.</p> <p>Audubon Society Christmas bird counts over 30 years have shown a decrease in the populations of the downy and hairy woodpeckers, as well as the northern flicker.</p>
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	<p>Diameter is the most important distinguishing characteristic of snags used for nesting and foraging. Snags and decadent trees greater than 38 cm (15in) dbh are used by some species for nesting and foraging, larger diameter snags (>51 cm/20in dbh) are preferred and offer optimal nesting and foraging conditions. Taller snags are also preferred (>18m/59ft).</p> <p>When creating snags, trees should be topped (chainsaw was shown to be the most effective method) 15-25m (50-82ft) above the ground. Wind firm conifers at least 51 cm (20 in) dbh should be selected. Live trees should be reserved around the created snags to provide better protection for the snag as well as higher wildlife use.</p> <p>Retaining live green trees around created snags in harvested areas also moderates the microclimate and thus encourages seedling and shrub growth as well as increasing wildlife use of the clearcut.</p> <p>Contrary to common opinion, retained trees do not act as a source of pests for the new developing forest. They actually serve as refuge and inocula for invertebrate fauna and mycorrhiza-forming fungi that are essential components of a new stand.</p> <p>Riparian Habitat Area Minimum Widths are reported in Table 4 of the document.</p> <p>Salvage logging should not be conducted if an area is being managed for the benefit of wildlife.</p> <p>Link below is to App B showing averages and minimums for snags in the Western Hemlock series (when using this table, Mark Hitchcock reports the following, Lake Chaplain is 70% site class 2, 25% class 3 and 5% class 1; Spada is 60% site class 3, 30% class 4, and 10% class 5)</p> <p>****SEE ALSO</p> <p>Y:\Regulatory Affairs\WILDLIFE\Relicensing_Study_Plans\SP6 Literature Review\Supporting Documents\Summary of Findings SP6 - Snags.xls</p> <p>AND</p> <p>Y:\Regulatory Affairs\WILDLIFE\Relicensing_Study_Plans\SP6 Literature Review\Supporting Documents\102 WDFW Snag Mgmt Recommendations App B.pdf</p>
221	<p>Larsen, E.M., Azerrad, J.M., Nordstrom, N., eds. 2004. Management recommendations for Washington's priority species: Vol. IV: Birds. Olympia, WA: WA St. Dept. Fish & Wildl. 280 p.</p> <p>1 - Very Relevant to Jackson WHMP</p>
193	<p>Larsen, E.M., ed. 1997. Management recommendations for Washington's priority species. Vol. III: Amphibians and Reptiles. WA Dept. Fish and Wildl. Olympia, WA. 122 p.</p> <p>1 - Very Relevant to Jackson WHMP</p>
83	<p>Lehmkuhl, J.F. 2005. Wildlife habitat fragmentation. 2005. Western Forester. November/December:8-9.</p> <p>Forest practices may result in gains for some species, while others may lose habitat, with corresponding short- and long-term effects on population size and persistence. Impacts depend on the species, their habitat requirements, population structure, life history, and the landscape context. Landscape-level issues of habitat distribution and connectivity across ownerships usually need to be addressed through collaboration among private and government land managers, especially for wide-ranging species.</p>
122	<p>Lewis, J. C. and J. M. Azerrad. 2003. Pileated Woodpecker. Pages 29-1 – 29-9 in E. Larsen, J. M. Azerrad, N. Nordstrom, editors. Management Recommendations for Washington's Priority Species, Volume IV: Birds. Washington Department of Fish and Wildlife, Olympia, Washington, USA.</p>

	<p>1 - Very Relevant to Jackson WHMP</p> <p>Most nests are in hard snags with intact bark and broken tops, or live trees with dead tops.</p> <p>PWP may use up to 11 roosts over a 3-10 month period.</p> <p>Cedar are often preferred as roost trees due to natural hollowing.</p> <p>Mature and OG forest are considered high quality habitat, but forests as young as 40 years are used if large residual snags are present.</p> <p>Shelterwood cuts and clearcuts are occasionally used if substantial foraging habitat is retained.</p> <p>Deciduous riparian habitat is used for foraging activities.</p> <p>Large snags are preferred foraging substrate, possibly because they harbor more insects and larvae than smaller snags.</p> <p>CWD is rarely used for foraging in wet coastal forests.</p> <p>Forest fragmentation may reduce population density and increase vulnerability to predation as the birds are forced to fly between fragmented forest stands.</p> <p>Management activities should focus on providing and maintaining large snags and large decaying live trees for nesting and roosting.</p> <p>Retaining snags and decaying live trees provides suitable nesting and roosting structure for a longer period than retaining/creating only hard snags.</p> <p>Trees, snags and stumps with existing PWP nest cavities and foraging excavations should be retained.</p> <p>Uneven-aged forest management can help to provide large trees and suitable canopy closure to maintain suitable nesting and roosting structure for PWP.</p> <p>Defective and cull trees should be retained during harvest operations.</p> <p>Extending harvest rotations may be one of the most effective means of providing large snags.</p> <p>Average values of given habitat components should be used as management goals.</p> <p>"Adequate snag densities are defined as the combination of nesting, roosting and foraging snag numbers"</p> <p>*** Recommendations: see supporting link</p>
123	<p>Lewis, J. C., M. Whalen, and R.L. Milner. 2002. Vaux's Swift. Pages 25-1 – 25-5 in E. Larsen, J. M. Azerrad, N. Nordstrom, editors. Management Recommendations for Washington's Priority Species, Volume IV: Birds. Washington Department of Fish and Wildlife, Olympia, Washington, USA.</p> <p>1 - Very Relevant to Jackson WHMP</p> <p>Vaux's Swift are highly dependent on large hollow trees and snags for nesting and roosting.</p> <p>Availability of these structures is suspected to be the limiting factor for this species.</p> <p>They require large hollow chambers in large snags or live trees for nesting and night roosting.</p>

	<p>Nest trees average 82' tall, and 27" dbh</p> <p>They rely on Pileateds for creation of nesting and roosting habitat.</p> <p>*** Recommendations:</p> <p>Leave all hollow snags and live trees intact (preferably > 20" dbh); Large defective trees, especially those with top rot, broken tops, other signs of rot or defects should be retained.</p>
228	<p>Linders, M.J., Stinson, D.W. 2006. Draft Washington state recovery plan for the western gray squirrel. Wildlife Program, WA Dept. Fish & Wildl. Olympia, WA. 99 pp. 1 - Very Relevant to Jackson WHMP</p>
101	<p>Lundquist, R.W. And J.M. Mariani. 1991. Nesting Habitat and Abundance of Snag-Dependent Birds in the Southern WA Cascade Range. In Wildlife and Vegetation of Unmanaged Douglas-fir Forests. USDA Forest Service, PNW-GTR-285. p 221-239. 1 - Very Relevant to Jackson WHMP</p> <p>For primary and secondary cavity nesters, the mean DBH of all active nest sites was 76 cm (range 18-167cm), and mean tree height was 25m (3-60m range). Mean nest tree diameters for all bird species were greater than 50cm. Snags in this size class were used disproportionately compared to availability in all forest age classes. Vaux's swifts were also found to use very large live trees and large snags. This study reports mean nest tree diameters that are larger than most other studies from the Olympic Peninsula, but smaller than the Oregon Coast Range. Nest sites contained higher densities of large, hard snags, concurring with other, earlier studies.</p> <p>***Mean nest tree diameters should be used as guidelines for management. Managing for minimums could cause gradual decline in cavity-nesting populations.</p> <p>***Recommend managing for snags with a minimum diameter of 76cm (the mean dbh of all active nests found).</p> <p>Snags 50cm dbh or greater should be given top priority in managing for cavity- and bark-nesting birds since this size is selected for disproportionate to its availability.</p> <p>By selecting the largest snags available, they will remain standing longer, retain bark linger and support of larger variety of wildlife.</p> <p>***Using the guidelines of Nitro 1985 would result in vastly underestimating the hard snags required west of the Cascades.</p> <p>Retaining more than the minimum required amount of snags allows for unforeseen loss due to windthrow as well as uncertain fall rates of snags.</p>
208	<p>Maguire, C.C. 2002. Dead Wood and the richness of small terrestrial vertebrates in southwestern Oregon. Gen. Tech. Rep. PSW-GTR-181. USDA Forest Service. Pp. 331-345.</p>
151	<p>Manning, J.A., Edge, W.D. 2004. Small mammal survival and downed wood at multiple scales in managed forests. J. Mammal. 85(1):87-96. 3 - Not Relevant to Jackson WHMP</p> <p>The authors sampled small mammals, understory vegetation and CWD at multiple scales (trap sites, 1-hectare patches and stands in 2 Douglas-fir forests in western Oregon. Study objectives: Do CWD or understory vegetation vary among or within forest patches or among forest stands? Does variation in small mammals survival coincide with the scale in which CWD or understory vary?</p>

	<p>Understory vegetation explain most of the variation within patches, but did not vary among patches or stands. Survival of deer mouse (<i>Peromyscus maniculatus</i>) and creeping vole (<i>Microtus oregoni</i>) varied within patches by differing among individual home ranges, and was most related to CWD volume and herb and grass cover. Survival of deer mice was explained by a polynomial function of CWD within individual home ranges, and peaked at 2.0 cu m per 0.01 ha. Survival of creeping voles was dependent on a negative log function of CWD within home ranges, and was highest in home ranges lacking CWD.</p> <p>Results indicate these species may not be generalists, but rather specialists tied to specific amounts of particular habitat components within home ranges.</p>
100	<p>Marcot, B.G. Annotated Review of Selected Literature on Snag Distribution. USDA Forest Service, PNW Region, July 17, 1988.</p> <p>1 - Very Relevant to Jackson WHMP</p> <p>Summary of selected literature on snag recommendations:</p> <ul style="list-style-type: none"> - Clumping snags in small patches enhances nesting habitat for the pileated woodpecker and other cavity nesting species. - The density and diversity of snags should be as great as possible, with the existing snag resource in an old, natural stand settings the upper limits (i.e. 11 snags/ha greater than 48cm dbh & 4.4m tall). - Retaining or creating large snags (greater than 60cm dbh & 15m tall) should receive particular emphasis. - Evenly distributed and clumped snag patterns best mimic natural conditions. - Managing for 100% population levels requires about 7 snags/acre, as this is what is seen in unmanaged forests. - Soft snags should not be counted, only large, hard snags. - A minimum level of snags to be left in a harvest unit should be set in addition to the background level of 7/ac, (i.e. on a 50 acre unit, 8-10% should be left in one snag habitat island).
78	<p>Marcot, B.G., Aubry, K.B. 2003. The functional diversity of mammals in coniferous forests of western North America. In: Zabel, C.J., Anthony, R.G., eds. Mammal community dynamics: management and conservation in the coniferous forests of western North America. New York: Cambridge Univ. Press:631-664.</p> <p>Proposes that the collective importance of terrestrial mammals to ecosystem structure and function is substantial and that the decline or loss of forest mammal species could have detrimental effects on ecosystem diversity, productivity, or sustainability.</p>
154	<p>Marshall, D.B. 1994. Status of the American Marten in Oregon and Washington. Unpublished Report. Portland, OR. Audubon Society of Portland. 46 p.</p> <p>2 - Somewhat Relevant to Jackson WHMP</p> <p>Literature review with section on timber harvest practices.</p> <p>Cites management recommendations of Corn and Raphael (1992) in Wyoming, and studies in California (Sierra Nevada): Martin and Barrett (1991), Hargis and McCullough (1984), Spencer (1981). See separate citations for these studies.</p> <p>Marten habitat requirements include high percentages of late-successional or mature and/or old-growth forests that can accommodate large home ranges. Habitat quality depends on mesic areas, high availability of prey, subnivean access where snow accumulates, a canopy level of at least 40%, and numerous denning sites. Denning sites include cavities in large snags and logs, and subterranean cavities under large logs, stumps and root wads. In the Pacific Northwest, martens use cavities in large diameter live trees and snags. Martens do not cross large open areas except when overhead cover is present, but will enter non-forested areas having cover in summer for berries.</p>

	<p>Forest fragmentation results in larger home range sizes and lower population sizes under late-successional or old growth conditions fall below the 30 to 50% level. Local extirpations then occur.</p>
162	<p>Martin, S.K., Barrett, R.H. 1991. Resting site selection by marten at Sagehen Creek, California. <i>Northw. Naturalist</i> 72:37-42.</p> <p>2 - Somewhat Relevant to Jackson WHMP</p> <p>Study results from California:</p> <p>"Preserving large snags and logs for marten and leaving cull logs after timber harvest should benefit marten." "Average densities (no. per ha) in known marten habitat in our study were 46 snags, 66 stumps, and 39 logs." "The diameter of snags, stumps, and logs left for marten should be 80 cm or greater. Snags should be at least 4m tall, stump heights at least 80 cm and log lengths at least 10 m."</p>
165	<p>Marzluff, J.M., J.J. Millspaugh, K.R. Ceder, C.D. Oliver, J. Withey, J.B. McCarter, C.L. Mason & J. Cornnick. 2002. Modeling Changes in Wildlife Habitat and Timber Revenues in Response to Forest Management. <i>For. Sci.</i> 48:191-202.</p>
230	<p>Mathiasen, R.L. 1996. Dwarf Mistletoes in Forest Canopies. <i>Northwest Sci.</i> 70:61-71.</p> <p>1 - Very Relevant to Jackson WHMP</p> <p>Spotted Owls, marbled Murrelet and several species of squirrels have been found to frequently use mistletoe brooms for nesting.</p> <p>Marten use brooms as resting sites.</p> <p>Sites with mistletoe are suspected of having much greater species diversity than mistletoe free sites.</p> <p>Studies in Colorado have shown that the number and abundance of passerine birds as well as cavity nesting birds is higher in these areas than in non-infested areas. Elk and deer activity was also higher in these stands.</p> <p>A more extensive list of species that are not rare or endangered and also use brooms is provided as well.</p>
270	<p>McNay, R.S., Davies, R. 1985. Interactions between black-tailed deer and intensive forest management: Problem analysis. Research, Ministries of Env. And Forests. IWIFRR-22. Victoria, B.C.</p>
67	<p>Mellen, K., Marcot, B.G., Ohmann, J.L., Waddell, K.L., Willhite, E.A., Livingston, S.A., Hostetler, B.B., Ogden, C., Dreisbach, T. 2006. DecAID - the decayed wood advisor for managing snags, partially dead trees, and down wood for biodiversity in forests of Washington and Oregon forests. Ver 2.0 US Forest Service, Pacific NW Region and Pacific NW Research Stn., Portland, OR.</p> <p>http://www.notes.fs.fed.us:81/pnw/DecAID/DecAID.nsf</p> <p>1 - Very Relevant to Jackson WHMP</p> <p>Computer program/management advisory tool.</p> <p>The DecAID database summarizes habitat associations of wildlife in terms of dead wood diameter and abundance. Can be used to determine either the species that would be provided for by retaining various densities and diameters of dead wood, or the levels of dead wood needed to provide habitat for species of interest.</p> <p>DEFINITIONS:</p> <p>Tolerance Level (TL) - an 80% tolerance level means that 80% of the population have a value for the given parameter that is between 0 and the value for the 80% TL. These are calculated based on 90% certainty levels. Example: an 80% TL of wildlife use of snag diameter means</p>

	<p>that 80% of all individuals observed uses snags less than or equal to some specified dbh, and 20% use snags greater than that dbh. The tolerance levels describe dead wood conditions across the total area within the vegetation condition.</p> <p>Large Tree - Single Story - Closed Canopy - QMD $\geq 20"$; grass, shrub & seedling may occur in understory. Canopy cover is $>70\%$; tree size is 20-29" dbh; single canopy stratum.</p> <p>Medium Tree - Single Story - Closed Canopy - QMD 10-19"; grass, shrub & seedling may occur in understory. Remnant trees can provide $<10\%$ canopy cover. Canopy cover is $>70\%$; tree size is 15-19" dbh; single canopy stratum.</p> <p>FINDINGS - Snags & Cavity Nesters, Mike:</p> <p>Selection for - Selection for a given habitat attribute provides stronger evidence of a species' need than mere inventory data.</p> <p>Uncarpeted Westside forests provide a reasonable estimate of historical conditions.</p> <p>Advise against managing an entire landscape towards a particular tolerance level. Instead, distribution of habitat attribute should be guided by the distribution from unharvested plots. Areas should be managed within the complete range of dead wood values to provide for all species on the curve.</p> <p>The value of live and dead hardwood trees and partially dead trees of all species, should not be overlooked.</p> <p>If the objective is to manage for natural conditions rather than focusing on wildlife species, mimic distribution of unharvested acres (unharvested proportion of the landscape) in different snag density classes across the landscape. The percentages should be thought of as guidelines, since distributions largely reflect plot size and sample design. Balancing high, moderate and low densities of dead wood across a landscape may be desirable.</p> <p>Species often use clumps of snag & dead wood. Numbers and sizes of clumps are not indicated by this data. Areas between clumps should not be devoid of snags; a mix of clumps and more widely distributed snags should occur at the stand level.</p> <p>SPECIFIC RECOMMENDATIONS:</p> <p>Clustered and scattered snags receive equal use for nesting and foraging.</p> <p>Provide a variety of tree species, hardwoods and white pine are highly selected when available.</p> <p>Particularly tall trees and snags (up to 110ft) are selected for, as roost trees by some bat species, esp. those that protrude above the canopy.</p> <p>Retain all hollow trees snags and logs. Cedar and hemlock are more susceptible to hollowing.</p> <p>Favor trees with fruiting fungal bodies, esp. of heart rot fungi, as well as forked tops, broken tops and brooms. These defective trees can substitute for some of the snags, counting towards density & dbh requirements.</p> <p>For 80% TL, manage for 36.4 snags/ac $\geq 10"$ dbh, with 14/ac $> 20"$ dbh. The complete range of diameters and densities should be managed for to provide for all species utilizing snags.</p> <p>Snags as large as 79" dbh should be provided for PWP roost trees. For all other species, snags $> 63"$ dbh should be provided.</p>
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These data will provide a CONSERVATIVE APPROACH to snag habitat management.

Wildlife use data and inventory data from unharvested plots both support managing snags at the 80% TL.

Several studies indicate that even higher densities of snags are justified on at least some of the landscape, (46.9/ac > 10" dbh and 14-20/ac > 19.7" dbh).
Snag densities such as these occur on 6-10% of the unharvested landscape.

The 80% TL for DBH of snags used by wildlife (nesting, roosting and foraging) ranges from 33 to 79" dbh. Most nest and roost snags are greater than 47" dbh. All roost trees found were > 43" dbh.

Snags > 39.4" dbh comprise about 7% of all snags measured, and occur on 54% of the unharvested lands in this vegetation condition.

The 80% TL for DENSITY of snags used by wildlife ranges from 19-36/acre >= 10" dbh, and 2-14/ac >= 20" dbh. For unmanaged stands aged 80 to 195 years, the 80% TL provides 46.9/ac >= 10" dbh and 13.9/ac >= 19.7" dbh.

LANDSCAPE DISTRIBUTION OF SNAGS IN NATURAL CONDITIONS:

Data collected from unharvested stands -

** 10% of the area has 36.4/ac >= 10" dbh, this is similar to most of the data points at the 80% TL for WILDLIFE.

** 19% of the area has 14.2/ac >= 19.7" dbh, this is similar to most of the data points at the 80% TL for WILDLIFE.

** 18% of the area has 12.1 to 18.2/ac >= 10" dbh, similar to the 50% TL.

** 40% of the area has 8.1/ac >= 19.7" dbh, similar to the 50% TL.

** 81% of the area has 6.1/ac >= 10" dbh, similar to the 30% TL.

** 37% of the area has 0 to 6.1/ac >= 19.7" dbh, similar to the 30% TL.

** 4% of the area has no snags >= 10" dbh.

** 5% of the area has no snag >= 19.7" dbh.

TREE HEIGHT:

Nest Tree Height ranged from 7' to 112'.

Foraging Tree Height ranged from 49' to 75'.

Den Tree Height for the N Flying Squirrel was 69'.

Roost Tree Height ranged from 72' to 144', with bat species recording the highest roosts, typically taller than the surrounding canopy, and snag height was noted as the most important criteria for selection of bat roost trees.

PWP selected for nest and roost trees that were >= 90' tall and against those < 57' tall. Increasing density of hard, tall snags led to an increase in abundance of hairy woodpeckers & red-breasted sapsuckers.

Cavity Nesting Birds in the S. Wa Cascades preferred nesting in white pine snags.

Based on tree availability, PWP on the Olympic Peninsula selected against hemlock and selected for Silver fir as nest trees and selected for cedar as roost trees.

Half of the nests and roost were found in decadent live trees, even though they were much more rare than snags.

Densities of dead top live trees around PWP nest and roost sites was higher than at random sites.

	<p>DISTRIBUTION OF SNAGS: **40% of the unharvested area and 30% of the total area supports > 18.2 snags/ac >= 10" dbh. ** 40% of the unharvested area and 29% of the total area supports > 8.1 snags/ac >= 19.7" dbh.</p> <p>Dwarf mistletoe is important for providing roosting and nesting structures for birds and small mammals. Hemlock is most susceptible, and therefore the most important for wildlife habitat. 14% of unharvested and 12% of harvested plots have some level of infection by mistletoe.</p> <p>Removing woody structure can have short-term benefits to planted seedling growth but longer-term adverse effects on overall forest productivity.</p>
92	<p>Mellen, T.K., E.C. Meslow and R.W. Mannan. 1992. Summertime Home Range and Habitat Use of Pileated Woodpeckers in Western Oregon. J. Wildl. Manage. 56:96-103. 1 - Very Relevant to Jackson WHMP Radio telemetry was used to track PWP over a 4 year period to determine home range and habitat use preferences in the Oregon Coast Range. Home range size for adult birds after young had fledged average 478ha (range 267 - 1,056 ha). This is larger than other studies have reported, but is one of the only at the time to have used radio telemetry. Nesting and roosting occurred only in stands older than 70 years, but they are known to forage in younger stands. Old growth habitat was selected for in proportions moderately greater than its availability (<1.5 times availability). Forests older than 70 years averaged 47% of home ranges (255ha).</p> <p>Nest trees (n = 18) average 71 cm dbh (range 40 - 138 cm) Roost trees (n = 15) averaged 112 cm (range 40 - 208cm)</p>
170	<p>Messere, M. and P.K. Ducey. 1998. Forest Floor Distribution of Northern Redback Salamanders, <i>Plethodon cinereus</i>, in Relation to Canopy Gaps: first year following selective logging. For. Ecol and Manage. 107:319-324. Study of amphibians within gaps in northern hardwood forests, focusing on Northern Redback Salamanders.</p>
68	<p>Morrison, M.L., Dedon, M.F., Raphael, M.G., Yoder-Williams, M.P. 1986. Snag requirements of cavity-nesting birds; are USDA Forest Service guidelines being met? West. J. Appl. For. 1:38-40. 1 - Very Relevant to Jackson WHMP Relevant, but written in 1986, and already a reference for the WHMP.</p>
17	<p>Muir, P.S., Mattingly, R.L., Tappeiner, J.C., Bailey, J.D., Elliott, W.E., Hagar, J.C., Miller, J.C., Peterson, E.B., Starkey, E.E. 2002. Managing for biodiversity in young Douglas-fir forests of western Oregon. US Geol. Surv., Biol. Res. Div., Biol. Sci. Report USGS/BRD/BSR -2002-0006. 76 pp. 2 - Somewhat Relevant to Jackson WHMP</p>
140	<p>Nelson, S.K. 1988. Habitat Use and Densities of Cavity Nesting Birds in the Oregon Coast Ranges. Corvallis, OR, USA. Oregon State Univ. Master's Thesis. 1988; 157p. 1 - Very Relevant to Jackson WHMP no PUD copy - available from OSU library.</p> <p>Abundance of many cavity nesting species, including Pileated WP (PWP) and red-breasted sapsuckers (RBS) increased with stand age and were positively associated with density of large conifers.</p> <p>Abundance of PWP was positively correlated with abundance of large (>50cm) class II & III</p>

	<p>snags, and has been reported by others to reach maximum in mature or old-growth forests.</p> <p>A negative association was found between cavity-nester abundance and the abundance of small snags and trees, common to young forests.</p> <p>Small snags (<50cm) were found to provide inadequate nest sites for flickers</p> <p>Most (70%) nests were located in class II & III snags with notes signs of decay, particularly conks of Fomes and exposed heartwood.</p> <p>Secondary cavity-nesters used class V snags more often than did primary excavators.</p> <p>Hairy WP and Flickers were found to avoid class V snags entirely, and nested predominantly in trees with not evidence of decay.</p> <p>** Mean nest tree diameter was 94cm.</p> <p>PWP only nested in class II & III snags.</p> <p>Of all primary and secondary cavity nesters, 70% (172 of 244 nests) nested in class II & III snags.</p> <p>Nest trees were taller, larger dbh and had more limbs than available snags.</p> <p>For nest trees, 86% of snags had broken tops, and 52% of live trees had broken tops.</p> <p>Decay class II & III snags were selected for, and classes I, IV & V were avoided, based on availability.</p> <p>*** 73% of nests were found in snags ≥ 50cm, with snags 50-99cm being used 2x their availability, and snags >99cm being used more than 4x their availability.</p> <p>*** Snags 21-30m tall were used 2.5x availability; 31-40m used 5.5x availability, and >40m used 9x availability.</p> <p>53% of all nest trees were decay class II or III and ≥ 50cm (the next highest use was of medium sized snags (20-49cm dbh) in classes II & III, at 18%). Class II & III snags were used in greater amounts than available.</p> <p>Mean nest tree height = 31m.</p> <p>Snags 50-99 cm & >99cm were used significantly more than available by PWP, hairy, flicker and sapsucker for nest trees.</p> <p>Snags 21-30m, 31-40m & >40m were all used in significantly greater proportions than available.</p> <p>Woodpecker species never nested simultaneously in the same snag.</p> <p>Ten snags were reused by the same species in successive years, but the same cavity was never utilized. These trees were typically (81%) in old-growth stands, in large (≥ 50 cm dbh), tall (>17m) hard snags (81% in classes I, II or III).</p> <p>Snag height and diameter were found to be the most important determinants in which snags were used for nesting, both being greater than available.</p>
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	<p>*** Use of tall (>40m), large (>=50cm) snags exceeded availability in all stand types.</p> <p>36% of live nest trees in mature forests (> 80 y.o..) were in live big-leaf maple, the remainder being in Douglas-fir.</p> <p>Cavity-nesting birds were found to nest in snag patches, containing high densities of medium and large snags, and dense midstory and understory cover.</p> <p>Cavity-nesters preferred to nest in areas with >48% midstory and understory cover, 59% of nests occurred in area with these high cover levels.</p> <p>*** Nest sites were more often found in areas with >= 11 medium or large (20-49 cm dbh or 50cm dbh +) snags/ha.</p> <p>*** Cavity nesters avoided sites with fewer than 1 medium of large snag/ha.</p> <p>*** Presence of supercanopy trees was significantly higher (9x) at nest sites than random sites.</p> <p>Across all stand types, birds preferred to nest in large (>= 50 cm dbh; >= 21 m tall), hard snags with numerous limbs. Subtle differences occurred among species in nest-tree preference for tree diameter, cavity height and decay condition.</p> <p>Douglas fir sapwood decays more rapidly than heartwood, so in large snags, this pattern may aid in cavity excavation and longevity, since it decays more slowly than many other species.</p> <p>Hemlock decays rapidly and may not meet birds' preferences for hard snags.</p> <p>70% of nests were found in snags from decay class II & III; exceeding availability in all stand types.</p> <p>The largest and tallest snags available were chosen for nest trees, with nests placed at the highest possible diameter.</p> <p>Large (>50cm dbh) Douglas-fir snags have been reported (Cline 1978) to last an average of 125 years in the PNW and up to 200 years before becoming a rotten stump. Snags <50 cm dbh are usually well decayed by 60 years (Cline 1980).</p> <p>Midstory and understory cover were important selection criteria in all stand types. These are often caused by natural canopy gaps and help to create an uneven vertical profile. Shrub cover has been found to be an important characteristic to cavity-nesting birds.</p> <p>Providing snag patches in managed forest would mimic the natural distribution of snags.</p> <p>Management for snags >=94cm dbh will provide for the greatest diversity of cavity-nesting birds.</p> <p>Managing for minimum diameters will likely provide sub-optimal habitat and may have negative effects on reproductive success.</p> <p>This study found that mean snag diameters for all species and minimum sizes for flickers exceeded the minimums suggested by Nietro et al. 1985.</p> <p>Managing for mean diameters is supported by this study.</p> <p>Mean snag height for all cavity nesters was 31m.</p>
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	<p>Only 27% of all nests were in snags <50 cm.</p> <p>*** Due to limited statistical differences found between nest-tree characteristics of all cavity-nesting species, managing for the needs of primary cavity nesters will also meet the needs of other snag dependent species.</p> <p>Cavity-nesters used snag patches associated with high midstory and understory cover, and a mean of 19 large snags/ha.</p> <p>*** Several species are highly unlikely to use snags in clearcuts; red-breasted nuthatch, brown creeper and PWP avoid nesting in clearcuts. Only management for mature (80-200 y.o.) and old growth forests or large sang islands will provide for the habitat needs of these interior forest species.</p> <p>Habitat islands within managed forests should also meet the needs of habitat generalists such as hairy wp, flickers and chestnut backed chickadees, although they have been found to nest in clearcuts.</p> <p>Red-breasted sapsuckers prefer dense midstory and understory cover, so leaving or creating large snags (>94cm) in dispersed patches in mature forests or in riparian strips may provide the necessary habitat.</p> <p>RECOMMENDATIONS:</p> <p>** Douglas fir snags meet the needs of most cavity nesters.</p> <p>** Preserve existing hard snags in classes II & III and retaining green trees for replacement.</p> <p>** Manage for mean sizes of trees; large snags (>94 cm, >31m tall) should be maintained and created in all intensively managed and unmanaged forests.</p> <p>** Stands larger than 40 ha will be required to create forest interior habitat and reduce edge effect. These areas should be virtually free of forest management activities.</p> <p>** In intensively managed forests, extending rotation age to >80 years will allow for creating or retaining larger snags which are most preferred.</p> <p>** Modified shelter wood cuts should be used in even-aged management stands. Retain 12-15 large (>= 50 cm) live trees/ha.</p> <p>** Snag habitat islands should include >19 large snags/ha (mean # from this study) and large live replacement trees with intact mid- and understory canopy. These areas should also include hardwoods, especially big-leaf maple. Each clearcut should have these habitat islands, to supply adequate distribution across the landscape.</p>
274	North, M., Greenberg, J. 1998. Stand conditions associated with truffle abundance in western hemlock/Douglas-fir forests. <i>For. Ecol. And Manage.</i> 112:55-66.
167	<p>North, M.P., J.F. Franklin, A.B. Carey, E.D. Forsman & T. Hamer. 1999. Forest Stand Structure of the Northern Spotted Owl's Foraging Habitat. <i>For. Sci.</i> 45:520-527.</p> <p>1 - Very Relevant to Jackson WHMP</p> <p>In the CART analysis a snag volume greater than 142.1m³/ha was correlated with an increase in foraging use from low to medium and high in these study areas.</p> <p>** 70% of the snag volume was derived from large snags (dbh >50 cm) rather than the small but numerous suppressed and intermediate dead trees.</p> <p>Snag sizes were variable on sample plots, but medium and high use areas often had large rot-resistant snags (cedar or Douglas-fir) resulting from the site's past disturbance.</p> <p>The size of large snags on medium and high foraging use areas averaged 86 cm dbh (SD 15.4) and 24 m tall (SD 14.3) with a mean density of 15/ha (SD 4.6)</p>
60	Nyberg, J.B., Janz, D.E., eds.1990. Deer and elk habitats in coastal forests of southern British

	Columbia. Res. Branch, BC Min.For., Victoria, BC. Spec. Rep. Serv. No.5.												
72	<p>Ohmann, J.L., McComb, W.C., Zumrawi, A.A. 1994. Snag abundance for primary cavity-nesting birds on nonfederal forest lands in Oregon and Washington. Wildl. Soc. Bull. 22:607-620.</p> <p>1 - Very Relevant to Jackson WHMP</p> <p>Snag abundance patterns were assessed based on plant community type and stand conditions on both managed and natural forests on nonfederal lands. Data should be considered averages for 14 million acres across these lands. Densities and snag characteristics were characterized for a wide range of stand conditions. Models of the snag-bird relationship were used in an attempt to predict the role of non-federal lands in providing habitat for primary cavity-nesters. Implications of forest management in the Northwest are also discussed. Mean ages of closed sapling-pole-sawtimber, open saw and large saw found on these lands are given. Detailed tables break down snags by diameter and decay class, and show mean density of snags for each of the above listed forest canopy types in coniferous forests as well as conifer-hardwood mixed forests. Based on the mean density & sizes of snags, old growth forest was the only cover type predicted to support 100% of the Maximum Potential Population of all species simultaneously.</p>												
284	<p>Olson, D.H., Hagar, J.C., Carey, A.B., Cissel, J.H., Swanson, F.J. 2001. Wildlife of Westside and high montane forests. In Johnson, D.H., O'Neill, T.A. Wildlife-habitat relationships in Oregon and Washington. Oregon State Univ. Press. Corvallis, OR. P. 187-212.</p> <p>2 - Somewhat Relevant to Jackson WHMP</p> <p>Patterns of bird communities in coniferous forests of western Oregon and Washington:</p> <ul style="list-style-type: none">• Majority of bird spp widely distributed within this zone• Avian community composition influenced by elevation, seral stage vegetation structure and composition, presence of water, and other special features.• Differences b/n seral stage most pronounced between very early open canopy (grass-forb-shrub) and closed canopy• Species richness of birds similar in early and late stages of forest development, and lowest in the structurally simple mid-seral stages of managed forests.• Key features influence presence of bird species: logs, rock substrates, litter, snags, large trees. Species that are most abundant in older forests will use early seral habitats if key structural features are present.• Abundance and diversity of birds positively correlated with the abundance of hardwood trees and shrubs, e.g. warbling vireos, MacGillivray's warbler, orange-crowned warbler, Wilson's warbler <p>Bird species associated with seral stages/vegetation height</p> <table><tr><td>Grass/forb trees (old growth)</td><td>Shrub/seedling</td><td>Sapling/pole</td><td>Small trees</td><td>Medium trees</td><td>Large & giant</td></tr><tr><td>61</td><td>92</td><td>98</td><td>130</td><td>140</td><td>140</td></tr></table> <p>Willow flycatcher, white-crowned sparrow, song sparrow, spotted towhee Pacific slope flycatcher, varied thrush, brown creeper, chestnut-backed chickadee, red-breasted nuthatch, hairy woodpecker Marbled murrelet, spotted owl, Vaux's swift</p> <ul style="list-style-type: none">• Diversity hotspots: old growth, riparian <p>Habitat elements</p> <ul style="list-style-type: none">• Surface rock, logs, duff/litter, snags, live trees, moss, cavities, shrubs, riparian <p>Forest Wildlife Assemblages</p> <ul style="list-style-type: none">• Examples: ground-dwelling small mammals, forest canopy mammals, cavity-nesting birds and mammals, terrestrial-breeding amphibians, pond-breeding amphibians, stream-breeding amphibians	Grass/forb trees (old growth)	Shrub/seedling	Sapling/pole	Small trees	Medium trees	Large & giant	61	92	98	130	140	140
Grass/forb trees (old growth)	Shrub/seedling	Sapling/pole	Small trees	Medium trees	Large & giant								
61	92	98	130	140	140								

	<ul style="list-style-type: none"> • Stream-breeding amphibians: torrent salamander, Cope's giant salamander, tailed frog, Pacific giant salamander • Terrestrial-breeding amphibians: Dunn's salamander, western red-backed, Van Dyke's. Some associated with rock (plethodontids) , some with downed wood (slender salamander, black salamander • Pond-breeders: red-legged frog, Cascades frog • Forest-floor small mammals:Trowbridge's shrew,southern red-backed vole, montane shrew, deer mouse, forest deer mouse, shrew-mole, creeping vole, vagrant shrew (+ others) • Arboreal rodent: northern flying squirrel, Douglas squirrel, Townsend's chipmunk • Good forest management leads to high diversity of small mammal and arboreal rodent assemblages <p>Forest management</p> <ul style="list-style-type: none"> • Federal: Northwest Forest Plan. Forest rotations and green tree retention levels matched to fire frequency intervals (100, 200 and 300 years) and intensities (15-50% retention)
268	<p>Parker, S., Hummel, S.S. 2002. Beyond 2001: a silvicultural odyssey to sustaining terrestrial and aquatic ecosystems. Proc. 2001 National Silviculture Workshop. May 6-10, Hood river, OR. Gen. Tech. Rep. PNW-GTR-546. Portland, OR: USDA Forest Service PNW Res. Stn. 114 p.</p>
238	<p>Parks, C.G., C.M. Raley, K.B. Aubry and R. L. Gilbertson. 1997. Wood Decay Associated with Pileated Woodpecker Roosts in Western Redcedar. Plant Disease 81:551.</p> <p>1 - Very Relevant to Jackson WHMP</p> <p>Short abstract:</p> <p>Large cedar that contain heart rot before they die persist longer and provide roost sites for a far longer time than other species.</p>
44	<p>Parks, C.G., Raley, C.M., Aubry, K.B. (and others). 1997. Wood decay associated with pileated woodpecker roosts in western redcedar. Plant Disease 81:551.</p> <p>1 - Very Relevant to Jackson WHMP</p> <p>Large cedar trees containing heart rot before they die may be especially important to PWP because these trees provide potential roost sites and will persist far longer than other tree species; they may even last for centuries.</p>
14	<p>Public Utility District No. 1 of Snohomish County and City of Everett, Washington. 1988. Wildlife Habitat Management Plan, Henry M. Jackson Hydroelectric Project, 3 Vol., Paging various.</p> <p>1 - Very Relevant to Jackson WHMP</p>
158	<p>Raley, C.M., and K.B. Aubry. 2006. Foraging Ecology of Pileated Woodpeckers in Coastal Forests of Washington. JWM 70:1266-1275.</p> <p>1 - Very Relevant to Jackson WHMP</p> <p>In wet coastal forests, dead trees (snags) and live trees with dead or broken tops (decadent trees) are commonly used for nesting by pileated woodpeckers (Aubry and Raley 2002a, Hartwig et al. 2004), whereas in drier inland forests, live trees are used much less frequently (Bull 1987, Bull et al. 1992b, McClelland and McClelland 1999).</p> <p>Did not search live trees with live tops for recent excavations because they were rarely used by pileated woodpeckers for foraging (9 of 412 structures used by radiomarked birds were live, intact trees; C. Raley and K. Aubry, unpublished data).</p> <p>The relative abundance of carpenter ants differed substantially between precanopy and closed-canopy habitat conditions; capture rates along logs</p>

	<p>and near cut stumps in pre-canopy stands were >10 times greater than capture rates in the same microsites in closed-canopy stands (Fig 2).</p> <p>Virtually all structures used by pileated woodpeckers for foraging were trees (93% snags and 2% decadent); 3% were cut stumps and 2% logs.</p> <p>Results of logistic regression analysis showed that pileated woodpeckers selected relatively tall, large-diameter snags in early to moderate stages of decay for foraging</p> <p>Fifty-seven percent of trees with recent foraging excavations were ≥ 81 cm diameter at breast height (median = 85 cm), 70% were ≥ 7.5 m tall (median = 15 m), and 52% had $\geq 75\%$ intact bark (median = 80%;). In contrast, trees without recent foraging excavations were smaller and more decayed; 76% were <81 cm diameter at breast height (median = 52 cm), 67% were <7.5 m tall (median = 5 m), and 58% had $<75\%$ intact bark (median = 40%;). Based on median values of diameter at breast height and height, the estimated volume of wood in trees used for foraging was 7 times greater than for trees that were not used.</p> <p>pileated woodpeckers selected sites for foraging that had greater densities of large (>51 cm dbh and ≥ 7.5 m tall) snags. Most (70%) plots with recent pileated woodpecker foraging activity had ≥ 3 large snags (median = 4). In contrast, plots with no recent foraging activity typically had <3 large snags (63%; median = 2).</p> <p>Despite the abundance of logs in coastal forests (Table 3), pileated woodpeckers rarely foraged on them.</p> <p>In the Coast Range of Oregon, $>50\%$ canopy cover greatly reduced the likelihood that carpenter ants (<i>C. modoc</i>) could successfully establish and maintain their nests (Nielsen 1986). This species was only found in forest clearings where there was enough solar radiation to warm the forest floor and associated coarse woody debris. Our results provide additional evidence that logs in coastal forests are too cool and wet to support abundant populations of carpenter ants.</p> <p>Snags used by pileated woodpeckers for foraging were larger in diameter and height and less decayed than those that were not used. Carpenter ant colonies are often large (Hansen and Antonelli 2005) and need correspondingly large structures to accommodate colony growth. Additionally, dampwood termite colonies nest and feed entirely within the host structure (Rosengaus et al. 2003). Thus, relatively large snags would provide greater volumes of wood and better habitat conditions for these arthropods over a longer period of time than small snags.</p> <p>Our results support our hypothesis that selection of foraging sites by pileated woodpeckers is influenced by the abundance of potential foraging structures.</p> <p>Despite the presence of potential foraging structures and large numbers of carpenter ants in open precanopy habitat conditions, they were rarely used by pileated woodpeckers for</p>
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	<p>foraging. Due to threat of predation, open habitats in coastal forests may provide inadequate escape cover for pileated woodpeckers.</p> <p>Current Forest Plan manages for nesting habitat for PWP, not for feeding or roosting. Our results indicate that maintaining populations of pileated woodpeckers in coastal forests may require a more comprehensive management strategy that also includes provisions for foraging (this study) and roosting (Aubry and Raley 2002a) habitat.</p> <p>To maintain or improve foraging habitat for pileated woodpeckers, we suggest that managers emphasize the retention of large (>51 cm dbh and >= 7.5 m tall), relatively hard snags. Additionally, we suggest that retaining patches of large snags (rather than dispersed structures) in closed-canopy habitat conditions would provide optimal foraging habitat for pileated woodpeckers.</p> <p>SEE SUPPORTING DOCS FOR DATA TABLE SUMMARY.</p>
260	<p>Raphael, M.G. et al. 2002. Effects of streamside forest management on the composition and abundance of stream and riparian fauna of the Olympic Peninsula. In: Johnson, A., Haynes, R. eds. Proc. of the wood compatibility initiative workshop. Gen Tech. Rep. PNW-GTR-563. Portland, OR: USDA Forest Service. Pac. NW Res. Stn.</p>
229	<p>Rodrick, E., Milner, R., tech. eds. 1991. Management recommendations for Washington's priority habitats and species. Wildlife Manage., Fish Manage., and Habitat Manage. Divs. WA Dept. of Wildlife. 206 pp.</p>
303	<p>Sallabanks, R., Arnett, E.B., Marzluff, J.M. 2000. An evaluation of research on the effects of timber harvest on bird populations. Wildl. Soc. Bull 28(4):1144-1155.</p> <p>3 - Not Relevant to Jackson WHMP</p> <p>A review of 95 studies published from 1972 to 1997 that examined relationships between timber harvest and songbird populations.</p> <p>Most research was short-term (1-2 yrs), not replicated, correlational and did not address cause-and-effect relationships. Most research included some habitat data but did not use multivariate analysis to examine bird-habitat relationships. Few studies measured avian demographic parameters such as nest success or survivorship; most studies measured avian density or abundance. Incorporating experimental treatments to provide pre- and post-timber harvest comparisons was rare.</p> <p>Future research should 1) be more long-term, 2) incorporate better experimental design, 3) measure parameters related to avian fitness and population viability. "Without detailed analyses of bird-habitat relationships using multivariate approaches, the specific structural attributes of forests that attract or deter birds may remain obscure. Knowing that a species is more abundant in a clearcut than nearby midsuccessional forest is useful information, but unless the key habitat elements (e.g., snag density, understory cover) responsible for the difference also are identified, precise management recommendations cannot follow."</p> <p>Cites Hayes et al 1998 for experimental design, including replication, randomized treatment plot, and length of data-gathering period.</p>
112	<p>Schreiber, B. And D.S. deCalesta. The Relationship Between Cavity-Nesting Birds and Snags on Clearcuts in Western Oregon. For. Ecol. And Manage. 50:299-316.</p> <p>1 - Very Relevant to Jackson WHMP</p> <p>Snag Diameter: Cavity Nesting Birds (CNB) utilized snags according to their availability, except that they avoided snags less than 28 cm, and selected for snags from 78-102 cm DBH. Many large diameter snags were short, decayed remnants and may have lacked some of the beneficial aspects of large-diameter snags suggested in other studies.</p>

	<p>Snag Height: Snags in all height classes greater than 6.4m were selected for</p> <p>Decay Class: Decay class 3 snags were selected for, and decay classes 1, 2 & 5 were avoided.</p> <p>Bark Cover: CNB as a group selected snags of significantly higher percent bark cover than available.</p> <p>A significant correlation was noted between CNB and snag density.</p> <p>***Recommend retaining or creating snags of the largest diameters possible, since they will stand longer.</p> <p>Snags that had been dead for 20-50 years were selected, and snags with either newer, harder wood, or snags with advanced deterioration were avoided.</p> <p>*** Recommend providing snags with a full range of bark cover, since high bark cover was preferred.</p> <p>When snag density was less than 10/ha, CNB density was 0.3 birds/ha or less, and was likely constrained by lack of nest sites.</p> <p>***Higher species richness and densities might accrue from snag densities > 25/ha.</p> <p>***Selecting snags with the most likelihood of CNB use may reduce the overall number required: a more realistic number of snags to leave on clearcuts might be the number found with nests (14/ha) is only snags of dbh, height, hardness and bark cover selected by CNB are retained.</p> <p>Recommend leaving 14 snags/ha., between 28 and 128+ cm dbh, 6.4 to 25m tall, 10-40%+ bark cover, most in decay stages 3 & 4.</p>
145	<p>Semel, B. And P. W. Sherman. 1995. Alternative Placement Strategies for Wood Duck Nest Boxes. Wildl. Soc. Bul. 23:463-471.</p> <p>2 - Somewhat Relevant to Jackson WHMP</p> <p>Conducted in Illinois, but some strategies are still applicable.</p> <p>Visible duplex boxes (traditional placement) were parasitized more often than hidden/dispersed boxes (non-traditional placement).</p> <p>Clutches in traditional boxes were less likely to hatch than those in non-traditional boxes (45% vs. 64%), resulting from brood parasitism.</p> <p>Ultimately, the same number of fledglings were produced from each box (9.0 in traditional vs. 9.2 in non-traditional), but a much greater number of unfledged ducklings resulted from the traditionally placed boxes (10.9 vs. 4.4, respectively).</p> <p>Among the findings:</p> <p>**Nest box placement and frequency of brood parasitism were directly related.</p> <p>** scarcity of unused boxes does not determine rate of parasitism.</p> <p>***full reproductive potential is more likely to be reached if boxes are placed inconspicuously.</p>
148	<p>Semel, B. and P. W. Sherman. 1992. Use of Clutch Size to Infer Brood Parasitism in Wood Ducks. JWM 56:495-499.</p> <p>2 - Somewhat Relevant to Jackson WHMP</p> <p>Parasitism is inferred from the following 4 criteria:</p>

	<p>** addition of ≥ 2 eggs in a 24 hour period; ** addition of eggs after incubation has begun; ** eggs that differ in color or shape from the remainder of the clutch: ** "supernormal" clutch size.</p> <p>Parasitism rates inferred from clutch size alone are unreliable.</p>
159	<p>Shirley, S.M. 2005. Habitat Use by Riparian and Upland Birds in Old-Growth Coastal British Columbia Rainforest. <i>Wilson Bul.</i> 117:245-257.</p>
143	<p>Specifications for meeting habitat requirements for pileated woodpecker and pine marten. 1990. Mt. Baker-Snoqualmie National Forest. Final EIS - Land and Resource Management Plan, Appendix H. Seattle, WA:USDA Forest Service, PNW Region, p. H-16 to H-23. 2 - Somewhat Relevant to Jackson WHMP May be out of date information, but see tables in Supportive Link</p>
169	<p>Spencer, W.D. 1981. Pine marten habitat preferences at Sagehen Creek, California. M.S. Thesis. Univ. of Calif., Berkeley, CA. 121pp. 2 - Somewhat Relevant to Jackson WHMP For forest stands adjoining riparian areas and meadows, "timber harvest should be by single-tree selection (maintaining 40-50% canopy closure) or small group selection (<0.25 ha). At least 8 snags/ha >38 cm dbh, including 1 >70 cm dbh, should be retained, along with 6 logs/ha >60 cm dbh. At least 12 fir trees/ha 70 cm dbh should be retained to provide for future snag recruitment."</p> <p>In more distant forest stands, "a greater variety of silvicultural practices are acceptable...where maintenance of habitat density and travel corridors are the major objectives. Clearcuts should be <100 m across with scattered trees left within them, and travel corridors of at least 30% canopy closure should be left connecting important habitats."</p> <p>Cited in Marshall, 1994</p>
189	<p>St. Clair, C.C., M. Belisle, A. Desrochers and S. Hannon. 1998. Winter Responses of Forest Birds to Habitat Corridors and Gaps. <i>Cons. Ecol.</i> Vol. 2, Article 13. 2 - Somewhat Relevant to Jackson WHMP Studied "gaps" in the sense of gaps between forested areas and their effect on willingness of birds to cross from one forested area to another. Chickadees were willing to cross a 25m opening, but as distance increased they chose detours through adjoining forest or habitat corridors. A gap of 200m was only crossed if no alternative was available.</p>
288	<p>Steeger, C. and M. Machmer. 1995. Use of Trees by Cavity Nesters in Managed and Unmanaged Interior Cedar-Hemlock Stands of Southern B.C. In: Bradford, P., T. Manning and B. l'Anson eds. <i>Wildlife Tree/ Stand-Level Biodiversity Workshop Proceedings</i>. Victoria, B.C. October 1995. 45-54. 2 - Somewhat Relevant to Jackson WHMP Study conducted in SE B.C.</p> <p>Mean dbh for active nest snags was 41.8cm Mean height for active nest snags was 20.6m</p> <p>Mean dbh for feeding trees was 30.3 cm Mean height for feeding trees was 13.4m</p> <p>Mean dbh of Douglas-fir used for bat roosts was 46.0 cm; mean height was 24.0 m, and a vast majority (55.6%) of these roost wee in woodpecker cavities.</p>

	Authors caution that if logging occurs during the main breeding season (May - July) that nestling bird and mammals occupying the nest trees will be unintentionally destroyed.
156	<p>Stephens, S.E., R. M. Kaminski, B. D. Leopold & P. D. Gerard. 1998. Reproduction of Wood Ducks in Large and Small Nest Boxes. Wildl. Soc. Bul. 26:159-167.</p> <p>3 - Not Relevant to Jackson WHMP</p> <p>Study conducted in Mississippi.</p>
61	<p>Stevenson, J.D., K.L. MacKenzie, and T.E. Mahon. 1998. Response of Small Mammals and Birds to Partial Cutting and Clearcutting in NW BC. Forestry Chronicle 74:703-713.</p> <p>2 - Somewhat Relevant to Jackson WHMP</p> <p>Alternative Silviculture Systems research initiative of the BC Ministry of Forests (under BC/Canada Forest Resources Devel. Agreement).</p> <p>Field study of small mammal and bird abundance after 2 intensities of partial cutting (LRT - 30% volume removal similar to single- tree and group selection system, and HRT - 60% volume removal similar to an irregular shelterwood system), compared to CC - clearcuts and UC - uncut stands.</p> <p>The 4 treatments differed primarily in tree basal area and proportion of area in canopy openings. Existing snag inventory dropped as result of harvest. Basal area of dead trees less after treatment than in UC. Mean diameter of both live and dead trees, and volume of downed logs, did not differ significantly by treatment, while the mean diameter of downed logs in CCs was significantly less than in UC.</p> <p>Small mammals: southern red-backed vole (<i>Clethrionomys gapperi</i>)(most abundant in all treatments), meadow vole (<i>Microtus pennsylvanicus</i>), deer mouse, common shrew, dusky shrew (<i>Sorex monticolus</i>).</p> <p>Red-backed vole more abundant in 1st year after LRT than UC. Other spp did not show significant differences by treatment, although the few meadow voles captured were all in CC.</p> <p>2nd year increase in deer mice and meadow voles. Red-backed voles most abundant in LRT, followed by UC and HRT, least abundant in CC. Deer mice more abundant in CC than UC. Meadow voles more abundant in CC than all other treatments. Shrews present in similar numbers in all treatments.</p> <p>Creation of openings in closed-canopy conifer forest increases small mammal abundance and diversity. With heavy canopy removal (CC or shelterwood), the most dramatic response is an increase in meadow voles and a decrease in red-backed voles.</p> <p>Birds: 34 spp used in analysis. Data combined for both post-treatment yrs. Bird communities in LRT and HRT more similar to UC than to CC, but limited sample size made it difficult to test for differences in detections of species as a function of treatment. Several spp (chestnut-backed chickadee and winter wren) had low abundance in CC, but no clear preference among the partial cuts and UC. Sapsucker and hairy woodpeckers frequently detected in CCs that had unharvested aspen trees with nest cavities, but foraged in nearby UC. Tree swallows also nested in tree cavities but only foraged in CC. Lincoln's sparrow and chipping sparrow only detected in CC. Robin and junco common in all treatments but most common in CC. Preference of Hammond's flycatcher for partial cuts was expected. Unexpected was the preference for partial-cut treatments by bark-cleaning spp (three-toed woodpecker, hairy woodpecker, brown creeper, red-breasted nuthatch). More results of this sort presented in this paper.</p> <p>General conclusions: HRT retained substantial abundance of most bird spp associated the UC, but was also used by some open-habitat spp more typical of CC.</p>

	<p>By varying the intensity and spatial pattern (dispersed or clumped) of timber harvest within a stand, can create the range of conditions favored by different guilds (see Hansen et al 1995 for definitions).</p> <p>The value of CC to some bird spp can be enhanced by leaving scattered individual mature trees or patches of trees.</p> <p>Limitations to this study and partial cutting: **With repeated harvest entries, expect a decline in abundance of snags and CWD **This study had abundant UC forest adjacent to treatment stands; may have influenced the use of treatment stands by some spp.</p>
308	<p>Sullivan, T.P., Sullivan, D.S. 2001. Influence of variable retention harvests on forest ecosystems. II. Diversity and population dynamics of small mammals. J. Appl. Ecol. 38:1234-1252. 3 - Not Relevant to Jackson WHMP</p> <p>Field study in southern BC in clearcut, single seed-tree, group seed-tree, patch-cut and uncut forest sites in Douglas-fir lodgepole-pine zone. Patch-cut system harvests timber from < 1 ha units dispersed over the stand. Experimental design described in Sullivan, Sullivan & Lindgren (2001).</p> <p>Hypothesis 1: The abundance and diversity of small mammals will decline with lower levels of tree retention. Contrary to hypothesis, mean total abundance of small mammals was similar among sites, and mean spp richness and diversity of small mammals was lowest in the uncut forest but similar across the 4 harvest treatments.</p> <p>Mean overall abundance of Microtus spp higher on clear-cut sites than single seed-tree, group seed-tree, patch-cut or uncut forest sites. Overall mean abundance of southern red-backed vole was similar in uncut forest and group seed-tree sites, which were both higher than patch-cut, clear-cut or single seed-tree sites.</p> <p>Recruitment of new Microtus spp differed significantly among sites, declining from clear-cut to uncut forest. Recruitment of red-backed vole exhibited the opposite trend. Survival of each vole species was similar across treatment sites.</p> <p>Hypothesis 2: The abundance, reproduction, and survival of Microtus spp. And southern red-backed vole populations will decline and increase, respectively, with the basal area and density of residual trees after harvest. This hypothesis was supported: Mean abundance of Microtus spp was inversely, and that of red-backed vole positively, related to mean basal area and density of residual trees after harvest. Mean abundance of Microtus spp also inversely related to percent cover and crown volume index of residual trees, and positively related to number of lodgepole pine cones in logging debris.</p> <p>Hypothesis 3: Habitat heterogeneity generated by variable retention harvest will limit Microtus, thereby reducing feeding damage to tree seedlings. Vole feeding damage to planted pine seedlings highest in the patch-cut sites, caused mainly by red-backed vole rather than microtines.</p> <p>The group seed-tree and patch-cut systems achieved both aims of maintaining red-backed vole and preventing microtine outbreaks.</p>
65	<p>US Forest Service. 1999. Dead and dying trees: essential for life in the forest. Science Findings 20. November 1999. 1 - Very Relevant to Jackson WHMP Mike:</p>

	<p>SNAGS: To create a hollow cavity, the decay process must begin early in the life of a live tree. Entrances used by wildlife are typically between 30 and 80 feet off the ground. Recent studies show that an increase in the number of snags per acre is needed if snags providing roosting, nesting, foraging, denning, shelter and resting are to be provided. Current Forest Service e guidelines and standards are inadequate.</p>
41	US Forest Service. 2000. If you take a stand, how can you manage an ecosystem? The complex art of raising a forest. PNW 27. September 2000.
96	<p>USDA Forest Service, PNW Region. 1990. Final EIS, Land and Resource Management Plan, Mt Baker-Snoqualmie National Forest, Appendix H. 1 - Very Relevant to Jackson WHMP Mike: Habitat requirements for the PWP to be used in their analyses include a minimum of 2 hard snags/acre ≥ 12" dbh within a 300 acre reproductive area for feeding. Forty-five of the 600 (0.15/ac) snags required should be ≥ 20" dbh.</p> <p>For the Pine Marten, providing at least these same minimums would ensure that adequate CWD is available for reproducing and feeding.</p>
285	<p>USDA Forest Service. 1994. Standards and Guidelines for Management of Habitat for Late-Successional and Old-Growth Forest Related Species Within the Range of the Northern Spotted Owl, Attachment A to the Record of Decision for Amendments to Forest Service and Bureau of Land Management Planning Documents Within the Range of the Northern Spotted Owl. 1 - Very Relevant to Jackson WHMP Mike's notes:</p> <p>Adequate numbers of large snags and green trees are especially critical for bats because these trees are used for maternity roosts, temporary night roosts, day roosts, and hibernacula. Large snags and green trees should be well distributed throughout the matrix because bats compete with primary excavators and other species that use cavities. Day and night roosts are often located at different sites, and migrating bats may roost under bark in small groups. Thermal stability within a roost site is important for bats, and large snags and green trees provide that stability. Individual bat colonies may use several roosts during a season as temperature and weather conditions change. Large, down logs with loose bark may also be used by some bats for roosting.</p> <p>Removal of snags following disturbance can reduce the carrying capacity for these species for many years.</p> <p>Regarding green tree areas, for many species, benefits will be greatest if trees are retained in patches rather than singly. Because very small patches do not provide suitable microclimates for many of these organisms, patches should generally be larger than 2.5 acres.</p> <p>To the extent possible, patches and dispersed retention should include the largest, oldest live trees, decadent or leaning trees, and hard snags occurring in the unit. Patches should be retained indefinitely.</p> <p>As a minimum, snags are to be retained within the harvest unit at levels sufficient to support species of cavity-nesting birds at 40 percent of potential population levels based on published guidelines and models. The objective is to meet the 40 percent minimum standard throughout the matrix, with per-acre requirements met on average areas no larger than 40 acres. To the extent possible, snag management within harvest units should occur within the areas of green-tree retention. The needs of bats should also be</p>

	<p>considered in these standards and guidelines as those needs become better known.</p> <p>Specifically, the Scientific Analysis Team recommends that no snags over 20 inches dbh be marked for cutting. The Scientific Analysis Team recognizes, however, that safety considerations may prevent always retaining all snags.</p> <p>Site-specific analysis, and application of a snag recruitment model (specifically, the Forest Service's Snag Recruitment Simulator) taking into account tree species, diameters, falling rates, and decay rates, will be required to determine appropriate tree and snag species mixes and densities. If snag requirements cannot be met, then harvest must not take place.</p> <p>Snag requirements are developed by the National Forests and BLM Districts for specific forest cover types, and these may be further broken down by geographic location. The intent is to tailor the requirements to those species that are actually expected to occur in an area.</p> <p>The most current available research will be used to determine to what degree the requirements for these other species are met by these snags or whether additional snags are needed to meet these other species objectives.</p>
146	<p>Utsey, F. M. And G. R. Hepp. 1997. Frequency of Nest Box Maintenance: Effects on Wood Duck Nesting in South Carolina. JWM 61:801-807.</p> <p>2 - Somewhat Relevant to Jackson WHMP</p> <p>Study was conducted in S. Carolina, but some results are applicable here:</p> <p>To maximize nest box use and duckling production, nesting materials should be removed after peak of nesting season and again immediately after the breeding season. This will also allow better estimates of nest box use, success and productivity.</p>
309	<p>WA. Dept. of Fish & Wildlife. January 2005. WDFW Management Recommendations for Washington's Priority Species: Pileated Woodpecker.</p> <p>1 - Very Relevant to Jackson WHMP</p> <p>WDFW PHS Birds Vol IV</p> <p>Pileated WP p 29-1 updated 2003</p> <p>http://wdfw.wa.gov/hab/phs/vol4/birdrecs.htm</p> <p>The breeding and nesting periods of the pileated woodpecker extends from late March to early July (Bull et al. 1990).</p> <p>Most nest cavities were observed in hard snags with intact bark and broken tops, or live trees with dead tops.</p> <p>Pileated woodpeckers may use up to 11 roosts over a 3-10 month period; however, some individuals will use one roost for a long period before switching to a new roost, while others regularly switch among several roosts (Bull et al. 1992b).</p> <p>Home ranges vary in size within the Pacific Northwest, ranging from 407 ha (1,006 ac)/breeding pair (data collected between June and March) in northeastern Oregon (Bull and Holthausen 1993), 480 ha (1,186 ac)/breeding pair during the summer in the central Oregon Coast Range (Mellen et al. 1992), and 863 ha (2,132 ac)/breeding pair annually on the Olympic Peninsula (Aubry and Raley 1996). The home range figures reported in the central Oregon Coast Range are likely smaller than the actual year-round home range for the pileated (Mellen et al. 1992).</p> <p>The removal of large snags, large decaying live trees and downed woody debris of the appropriate species, size and decay class eliminates nest and roost sites and foraging habitat.</p>

	<p>Intensively managed forests typically do not retain these habitat features (Spies and Cline 1988).</p> <p>fragmentation of forested habitat may lead to reduced population density and increased vulnerability to predation as birds are forced to fly between fragmented forested stands;</p> <p>General Recommendations Specific management prescriptions should be developed for actions that will be undertaken at the home range scale</p> <p>Trees, snags and stumps with existing pileated nest cavities and foraging excavations should be retained (Bonar 2001).</p> <p>Properly conducted uneven-aged management of forest stands can create adequate canopy closure and sufficient large snags and large decaying live trees to maintain suitable nesting and roosting habitat for pileated woodpeckers. Defective or cull trees can be retained during commercial thinning operations, or these can be recruited to become snags in subsequent rotations (Neitro et al. 1985). Because of the difficulties in recruiting large snags in managed forests (Wilhere 2003), one of the most effective means to improve snag densities may involve extending the length of harvest rotations (Neitro et al. 1985).</p> <p>The following set of recommendations is based primarily on average (rather than minimum) standards.</p> <p>The PIF (Partners in Flight) recommendations for managed coniferous forests (stands with >70% conifer stems) of about 60 years of age or older include maintaining >70% canopy closure and an average of >5 nest snags/10 ha (2 snags/10 ac) that are >76 cm dbh (30 in). In areas used for both nesting and roosting, an average of 18 large snags/ha (7 snags/ac) and 8 decaying large trees/ha (3 trees/ac) should be retained (Aubry and Raley 2002b).</p> <p>trees between 155 and 309 cm dbh (61-122 in) should be retained for roosting. In addition, an average of 30 foraging snags/ha (12 snags/ac) (mix of hard and soft snags) should be provided in the following size classes (see Table 3; Altman 1999).</p> <p>Adequate snag densities are defined as the combination of nesting, roosting and foraging snag numbers (see above).</p> <p>Suggested number of foraging snags to retain: 10-20" = >= 7/ac 20-30" = >= 3/ac >30" = >= 2/ac</p> <p>General Recommendations •Maintain large snags and large decaying live trees for nesting and roosting •Retain naturally formed stumps and numerous large logs in various stages of decay to improve foraging habitat •Use average size standards (rather than minimums) for managing pileated woodpecker habitat components (e.g., nest size standards).</p> <p>Western Washington •Maintain managed coniferous forests (stands with >70% conifer stems) of about 60 years of age or older at >70% canopy closure and an average of >5 nest snags/10 ha (2 snags/10 ac) that are >76 cm dbh (30 in) •Retain an average of 18 large snags/ha (7 snags/ac) and 8 decaying large trees/ha (3 trees/ac) in areas used for both nesting</p>
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	<p>and roosting</p> <ul style="list-style-type: none"> • Retain trees >27.5 m (>90 ft) in height to provide nesting and roosting structures. Trees between 155 and 309 cm dbh (61-122 in) should be retained for roosting • Retain an average of 30 foraging snags/ha (12 snags/ac)
305	<p>WA. Dept. of Fish & Wildlife. January 2005. WDFW Management Recommendations for Washington's Priority Species: Cavity Nesting Ducks. 2p.</p> <p>1 - Very Relevant to Jackson WHMP</p> <p>Recommend a minimum density of 5 potential nest cavities/acre within 0.5 miles of wetlands.</p> <p>Separate nest boxes by 150' or more to reduce predation.</p>
306	<p>WA. Dept. of Fish & Wildlife. January 2005. WDFW Management Recommendations for Washington's Priority Species: Vaux's Swift. 1p.</p> <p>1 - Very Relevant to Jackson WHMP</p> <p>Timber management plans should provide for long rotations (>200 years) and retain large hollow snags and live defective trees for future snag replacement (>20" dbh).</p> <p>Large defective trees with signs of decay (top rot, broken tops, fungal conks, dead branch stubs and other defects) should be retained.</p> <p>Chimney trees occupied by nesting or roosting swifts should not be disturbed between May and September.</p>
24	<p>Waldien, D.L., J.P. Hayes and B.E. Wright. 2003. Use of Conifer Stumps in Clearcuts by Bats and Other Vertebrates. NW Sci. 77: 64-71.</p> <p>1 - Very Relevant to Jackson WHMP</p> <p>Inventories of stumps in recent clearcuts found that use was restricted to warm/dry weather, when thermoregulation by bats and amphibians/reptiles would be beneficial.</p> <p>Even bats known to roost in stumps (Long-eared myotis) were less common if snags were at low densities within 2.5 km of the site.</p> <p>Limited snag resources may limit populations of forest-dwelling bats.</p>
139	<p>Walter, S. T. and C. C. Maguire. 2005. Snags, Cavity-Nesting Birds, and Silvicultural Treatments in Western Oregon. JWM 69:1578-1591.</p> <p>1 - Very Relevant to Jackson WHMP</p> <p>Large snags (>50cm dbh & 15m tall) are used disproportionately more than small snags.</p> <p>Experiment included creation of snags in clusters (8-12 snags) and scattered snags in 3 stand treatments: group-selection (33% volume removed in 0.2 to 0.6 ha patches), two-story stands (75% volume removed uniformly, leaving 20-30 scattered mature trees/ha, and clearcuts (with 1.2 green trees/ha retained).</p> <p>Created snags were saw-topped 10-12 years prior to study.</p> <p>19.9% of created snags were noted to have cavity-nesting.</p> <p>Live-topped conifers had low amounts of cavity excavation (7.8%), no active nests and low amounts of sapwood decay.</p> <p>1 active cavity was noted/4.9 created snags.</p> <p>Active cavities were 2.9x more abundant in clearcuts than in group-selection cuts.</p>

	<p>No difference in number of active nests or evidence of foraging found between clumped and scattered snags.</p> <p>Cavity nesting birds did not respond to Silvicultural treatment or snag arrangement, but active cavity numbers did increase from group-selection to 2-story to clearcut stands.</p> <p>Created snags with intact branches had higher incidence of cavity excavation.</p> <p>Snags in 2-story stands had 1.7x more cavities than snags in group-selection stands; no difference was found between group-selection and clearcuts or between 2-story and clearcuts.</p> <p>2-story stands and clearcuts with similar snag densities had more cavity nests, higher species richness, greater species diversity, and more similar communities of cavity-nesting birds compared to group-selection stands. Open canopy stands typically see increased vertical and horizontal structural diversity resulting from increased light input. This results in longer tree crowns and epicormic branching. These structures and snags provide habitat for many insects that are eaten by cavity-nesting birds. ***The low number of foraging events observed on snags indicates that much feeding activity occurs elsewhere.</p> <p>Chainsaw-topped snags began to be used for nesting within 4 to 6 years after creation.</p> <p>Topped snags were consistently more often used for foraging and nesting within the first 9 years due to accelerated decay caused by exposure of the inner wood following crown removal.</p> <p>**Silvicultural treatments resulting in open-canopy stands of mature conifers promote diverse stand structures that support more species and greater abundance of cavity-nesting birds than found in closed-canopy forests with equal snag densities.</p> <p>** A mix of stand conditions is required to meet the needs of all species capable of populating an area.</p>
232	<p>Walters, E.L. and E.H. Miller. 2001. Predation on Nesting Woodpeckers in British Columbia. Can. Field Nat. 15:413-419.</p> <p>3 - Not Relevant to Jackson WHMP</p> <p>Primarily discusses predation by bears, deer mice and house wrens as well as long-tailed weasel on cavity nesting species, but no recommendations as to sizes or species of trees to attempt to reduce this.</p>
234	<p>Waterhouse, F.L., A. S. Harestad and P. K. Ott. 2002. Use of Small Streams and Forest Gaps for Breeding Habitats by Winter Wrens in Coastal British Columbia. Northwest Sci. 76:335-346.</p> <p>2 - Somewhat Relevant to Jackson WHMP</p> <p>Wrens selected streams ≤ 10m wide, even though those < 5m wide tended to dry up during the breeding season.</p> <p>The area within 5m of stream banks was most important for winter wren nest sites.</p> <p>Canopy gaps were also found to be important habitat sources in both upslope and riparian areas due to the nature of gap creation (rootwads, stumps, down trees etc that are used as song perches).</p>
55	WDFW. 2006. Comprehensive Wildlife Conservation Strategy.
175	Weikel, J.M. and J.P. Hayes. 1999. The Foraging Ecology of Cavity-Nesting Birds in Young Forests of the Northern Coast Range of Oregon. Condor 101:58-66.

	<p>1 - Very Relevant to Jackson WHMP</p> <p>Although woodpeckers sometimes do forage on the same types of snags that they use for nesting (Mannan et al. 1980), there is no information indicating whether management strategies that focus only on nesting habitat would provide adequate foraging habitat to support woodpecker populations. Furthermore, current management strategies rarely consider foraging needs of cavity-nesting species other than woodpeckers.</p> <p>All four species of cavity-nesting bird showed selectivity in use of foraging substrates. Chestnut-backed Chickadees foraged frequently on live trees (Fig. 1), and was the only species observed foraging on shrubs. When foraging on shrubs, they were observed exclusively, and about equally, on vine maple and huckleberry. they selected hardwoods over conifers in relation to their availability (Table 2).</p> <p>Red-breasted Nuthatches foraged mostly on live conifers, but occasionally used snags (Fig. 1), and selected live trees that had larger diameters and fewer crown connections than did randomly chosen live trees (Table 2).</p> <p>The only species to forage substantially on snags and logs was the Hairy Woodpecker (Fig. 1). When foraging on live trees, Hairy Woodpeckers selected deciduous over coniferous trees and selected trees that had larger diameters than did randomly chosen live trees (Table 2).</p> <p>Hairy Woodpeckers selected snags that had larger diameters than did randomly chosen snags, and selected logs that had larger diameters</p> <p>Chestnut-backed Chickadees, Red-breasted Nuthatches, Brown Creepers, and Hairy Woodpeckers showed selectivity in use of foraging substrates. Deciduous trees, large diameter conifers, large diameter heavily decayed snags, and large diameter heavily decayed logs were important components of foraging habitat.</p> <p>Red alder, the most abundant deciduous tree species in our study area, may support a high diversity and abundance of arthropods (Furniss and Carolin 1977, Oboyski 1995). Many of the orders of arthropods found on red alder are important in the diet of adult and nestling Chestnut-backed Chickadees (Lepidoptera, Hymenoptera, and Hemiptera; Beal 1907, Kleintjes and Dahlsten 1992) and adult Hairy Woodpeckers (Coleoptera; Beal 1911, Otvos and Stark 1985). Schimpf and MacMahon (1985) found that arthropod density was higher in canopies of deciduous aspen forests than in canopies of coniferous forests. Because abundance of arthropods may be higher on deciduous than on coniferous trees, deciduous trees within a conifer-dominated landscape likely provide valuable foraging habitat for cavity-nesting birds.</p> <p>Management of nesting resources without regard to foraging resources is probably inadequate to provide habitat for cavity-nesting birds. We contend that in order to effectively manage habitat for cavity-nesting birds, foraging habitat, as well as nesting habitat, should be provided. In young conifer-dominated forests of the Pacific Northwest, patches of hardwoods, large diameter conifers, and large diameter snags and logs should be retained when logging. Legacy snags (large diameter snags from the previous stand) in young forests are especially important resources for cavity-nesting birds both as nesting (Mannan et al. 1980, Lundquist and Mariani 1991) and foraging substrates (Mannan et al. 1980, this study)</p>
276	Wilkins, R.N., Peterson, N.P. 2000. Factors related to amphibian occurrence and abundance in headwater streams draining second-growth Douglas-fir forests in southwestern Washington. <i>For. Ecol. And Manage.</i> 139:79-91.
227	Woodruff, K. Ferguson, H. 2005. Management recommendations for Washington's priority species: Vol. V. Mammals. Townsend's big-eared bat. WA Dept. Fish & Wildl., Olympia, WA. 13 pp.
	2 - Somewhat Relevant to Jackson WHMP

58	WSU Coop. Extension. 1998. Managing deer on small woodlands. Woodland Fish and Wildlife. WSU Cooper. Extension. MISC0189 Rev. July 1998.
98	<p>Zarnowitz, J.E. and D.A. Manuwal. 1985. The Effects of Forests Management on Cavity-Nesting Birds in Northwestern WA. J. Wildl. Manage. 49:255-263.</p> <p>1 - Very Relevant to Jackson WHMP</p> <p>Study was conducted on the Olympic National Forest in 1980 but provides recommendations for snag allotments as well as densities of cavity nesting species. Four different successional stages were evaluated for their snag densities and corresponding secondary cavity-nesting species (SCN). Populations of SCN increased with increasing snag densities. Hairy woodpeckers were noted to select Hemlock for their nest sites. When compared to mean dbh of all snags, the average dbh of active nest trees was significantly greater.</p> <p>Densities of primary cavity nesters (PCN) and SCN considered (Vaux's Swift, Northern Flicker, Pileated & Hairy woodpeckers) varied between 4.9 and 9.8 pairs/40ha in 60-120 yr old stands containing roughly 12-60 hard snags/ha. In old growth stands, populations ranged from 5.4 to 6.3/40 ha and contained roughly 30-59 hard snags/ha. Both the density and the species diversity of cavity nesting birds increased as the density of snags increased.</p> <p>The average nest tree was 16m tall, versus the average height of all sampled snags (9.6m).</p> <p>Management recommendations:</p> <ul style="list-style-type: none"> - Retain minimum of 6 hard and 3 soft snags/ha harvested. This is the minimum for maintaining cavity nesting bird populations. - "The bulk of snags" should be greater than 50cm as well as some >23cm and some > 75cm dbh in all successional stages. - A mixture of snag species should be left, especially hemlock and Douglas-fir.
157	<p>Zicus, M.C. 1990. Nesting Biology of Hooded Mergansers Using Nest Boxes. JWM 54: 637-643.</p> <p>3 - Not Relevant to Jackson WHMP</p> <p>Study conducted in Minnesota</p>
181	Ziegltrum, G.J. 2004. Efficacy of black bear supplemental feeding to reduce conifer damage in western Washington. J. Wildl. Manage. 68(3):470-474.

Appendix 2

References Arranged by Document Number

Document Number	Citation
0014	Public Utility District No. 1 of Snohomish County and City of Everett, Washington. 1988. Wildlife Habitat Management Plan, Henry M. Jackson Hydroelectric Project, 3 Vol., Paging various.
0016	Hartwig, C.L., D.S. Eastman and A.S. Harestad. 2002. Forest age and relative abundance of pileated woodpeckers on southeastern Vancouver Island. In: Laudenslayer, W.F. et al. eds. Proc. Of the Symposium on the Ecology and Management of Dead Wood in Western Forests. PSW-GTR-181. pp. 247-256.
0017	Muir, P.S., Mattingly, R.L., Tappeiner, J.C., Bailey, J.D., Elliott, W.E., Hagar, J.C., Miller, J.C., Peterson, E.B., Starkey, E.E. 2002. Managing for biodiversity in young Douglas-fir forests of western Oregon. US Geol. Surv., Biol. Res. Div., Biol. Sci. Report USGS/BRD/BSR -2002-0006. 76 pp.
0018	Franklin, J.F., Berg, D.R., Carey, A.B., Hardt, R.A. 2006. Old-growth conifer forests in Restoring the Pacific Northwest. Dean Apostol & Marcia Sinclair, eds., Society for Ecological Restoration International. Island Press: Washington DC. Pp. 97-121.
0019	Aubry, Keith B. and Catherine M. Raley. Landscape-Level Responses of Pileated Woodpeckers to Forest Management and Fragmentation: A Pilot Study. Progress Report 1990 and 1991. USDA Forest Service PNW Research Station. January 8, 1992. 73p.
0020	Mellen, T.K. 1987. Home Range and Habitat Use of Pileated Woodpeckers, Western Oregon. La Grande, OR. Oregon State University. Master of Science Dissertation. 96p.
0021	DNR. 1997. Final Habitat Conservation Plan. Washington Department of Natural Resources, Olympia, WA. Paging various.
0022	Western Forestry and Conservation Association. 2006. Managing for Wildlife Habitat in Westside Production Forests. Proceeding of a Workshop on October 18, 2006. Vancouver, WA.
0023	Scherer, G.m Zabowski, D., Java, B, Everett, R. 2000. Timber harvesting residue treatment. Part II. Understory vegetation response. Forest Ecology and Management 126:35-50.
0024	Waldien, D.L., J.P. Hayes and B.E. Wright. 2003. Use of Conifer Stumps in Clearcuts by Bats and Other Vertebrates. NW Sci. 77: 64-71.
0025	Gray, A.N., Spies, T.A. 1996. Gap size, within-gap position and canopy structure effects on conifer seedling establishment. J.Ecology 84:635-645.
0026	Gray, A.N., Spies, T.A. 1997. Microsite controls on tree seedling establishment in conifer forest canopy gaps. Ecology 78(8):2458-2473.
0027	Carey, A.B., Curtis, R.O. 1996. Conservation of biodiversity: a useful paradigm for forest ecosystem management. Wildl. Soc. Bull. 24(4):610-620.
0028	US Forest Service. 2002. Canopy gaps and dead tree dynamics: poking holes in the forest. Science Findings. PNW 43.

Document Number	Citation
0029	N. Am. Weed Mgt. Assn. 2002. North American Invasive Plant Mapping Standards. North Amer. Weed Manage. Assn. May 7, 2002. 34 p.
0030	US Forest Service.2004.Dead wood, living legacies:habitat for a host of fungi. Science Findings. PWN 66.
0031	US Forest Service. 2006. If a tree falls in the woods, who will measure it? DecAID decayed wood advisor. Science Findings. PNW 83.
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Appendix 4

Summary of Relevant Potential Alternative Management Techniques

CURRENT PRACTICES	POTENTIAL RELEVANT ALTERNATIVE TECHNIQUES	IMPLEMENTATION DETAILS	BENEFITS
FOREST VEGETATION MANAGEMENT			
Non-Harvest Stands:			
<p>Preserve and manage existing old-growth (OMA) stands with minimal intervention. Remove overstory trees when necessary to maintain target snag densities. Younger stands may be thinned or patch cut (<1 ac),</p> <p>Maintain mixed forest (PMF) and deciduous forest on Lake Chaplain Tract and wetland BZ at Lost Lake Tract without overstory harvest. Patch cutting is allowed.</p>	Canopy gaps.	Create canopy gaps in closed-canopy stands.	Canopy gaps promote development of shrub and herb layers, and allow snag creation.

CURRENT PRACTICES	POTENTIAL RELEVANT ALTERNATIVE TECHNIQUES	IMPLEMENTATION DETAILS	BENEFITS
60-Year Rotation Stands:			
Lake Chaplain Tract: Harvest units ≤ 26 ac. Clearcutting with 5% GTR (future replacement snags) located at edge of unit.	Increased green tree retention (GTR) distributed through harvest unit	Dispersed GTR – live trees are retained dispersed through the harvest unit, or Aggregated GTR – live trees are clumped patches scattered through the harvest unit. Increased GTR may be suitable on sites that are not appropriate for commercial thinning.	Increasing the GTR for a unit would promote additional long-term objectives, including a multi-storied canopy and increased structural diversity of the stand. Logging operations are likely to be more efficient with aggregated GTR, and mortality of retained trees lower.
Reforestation with Douglas-fir at 325-350 tpa	Replant at lower density. Plant and preserve a greater variety of tree species. Protect desirable hardwoods during harvest.	Replant a mixture of species at 250 tpa, or manage stand to promote a greater variety of conifers.	Promotes tree canopy species diversity and understory. Reduces need for PCT. A reduced planting density reduces need for thinning young trees. The herb layer will persist longer with reduced planting density.
Precommercial thinning, as needed, to result in 190 tpa	Avoid PCT.	Avoid PCT by planting 250 tpa after harvest.	If necessary, thinning young stands promotes development of shrub and herb layers.
Commercial thinning at age 40+.to 60% canopy closure.	Variable density thinning (VDT)	Site-specific	Promotes structural diversity of canopy layer; promotes shrub and herb understory.
Timing of harvest in some units to avoid deer fawning period (mid-May to June)	Timing of harvest should avoid main wildlife breeding period.	Restrict harvest activities to avoid May - July.	Shifting harvest to drier months reduces the likelihood of nest and nestling destruction, and less ground compaction will result.

CURRENT PRACTICES	POTENTIAL RELEVANT ALTERNATIVE TECHNIQUES	IMPLEMENTATION DETAILS	BENEFITS
Lost Lake Tract: Harvest units \leq 8 ac. Clearcutting with 5% GTR (future replacement snags) for Stand 7-2 only.	VDT, if needed to promote mixed forest condition.	Revisit scheduled harvest units to determine whether habitat conditions warrant removal of trees.	At present, stands on Lost Lake Tract that were scheduled for harvest provide adequate mixed forest habitat for wildlife species.
Replant with mixture of species to ensure 30% deciduous trees at stand age 45 years	If scheduled harvest is postponed or eliminated, increase tree species diversity	Manage units for shade-tolerant species and deciduous species through gap creation.	Promotes tree canopy species diversity and structural diversity.
SNAG MANAGEMENT			
Non-Harvest Stands:			
WHMP prescriptions currently call for creation of snags in 4 size classes, including 25" dbh and larger.	Create <u>roosting</u> snags based on current literature recommendations.	Top smaller trees around large candidate trees to increase growth for future snag creation.	Larger snags last longer, reducing replacement costs. (Increased contracting cost of topping due to increase in size of trees.)
		Reduce total # snags/acre required by trading out multiple small snags (10-20" dbh) for equal \$ value of 20"+ snags, as has been done in the past. Well distributed clumps and small pockets of snags should be used to ensure adequate distribution.	Utilize live-tree topping, cavity creation and inoculation of fungi to create large live roost trees. Trees in the 20" and greater size class are common on the Lake Chaplain Tract, with smaller trees becoming rarer. Suppression mortality will also add snags to the smaller size classes.

CURRENT PRACTICES	POTENTIAL RELEVANT ALTERNATIVE TECHNIQUES	IMPLEMENTATION DETAILS	BENEFITS
SNAG MANAGEMENT			
Non-Harvest Stands (cont.):			
	Clump and disperse snags		Dispersing across the landscape reduces likelihood of large losses from local windthrow events and reduces territorial issues among cavity nesting birds.
WHMP prescriptions currently call for creation of snags in 4 size classes, including 25" dbh and larger.	Create <u>nesting</u> snags at sizes based on current literature recommendations	Top smaller trees around large candidate trees to increase growth for future snag creation.	(Increased contract cost of topping due to increase in size of trees.) Trees up to approx. 40" dbh exist on the Lake Chaplain Tract, uncertain as to #/acre, but more are produced each year as stands age.
SNAG MANAGEMENT			
60-Year Rotation Stands:			
WHMP prescriptions currently call for creation of snags in 4 size classes, including 25" dbh and larger.	Continue WHMP prescriptions on harvest units, but utilize current research for snag sizes and aggregation of snags.	Reduce total # snags/acre required by trading out multiple small snags (10-20" dbh) for equal \$ value of 20"+ snags, as has been done in the past.	Timber cruise data and adequate distribution across the landscape should be used to determine which units are managed at the higher or lower snag sizes and densities.
		Create in green tree patches & in conjunction with buffer zones to reduce unsafe work area.	Large live trees and snags will have to be marked for protection during harvest, or bounded out of harvest area.

CURRENT PRACTICES	POTENTIAL RELEVANT ALTERNATIVE TECHNIQUES	IMPLEMENTATION DETAILS	BENEFITS
SNAG MANAGEMENT			
60-Year Rotation Stands (cont.):			
		Retain largest trees in buffers and GTA's during harvest to provide potential large live trees & snags in the future.	Clumping of snags greatly reduces work restrictions.
		Reduce planting density or thin around large trees to increase growth rate.	Trading multiple small trees for fewer large trees reduces actual number created, thereby reducing work area restrictions.
Snags are typically topped with the intention of killing the tree.	Create and protect decadent live trees.	Live-topping of the largest available trees will provide roosting habitat. Protecting existing decadent and hollow trees preserves existing habitat and reduces need to create additional. Inoculation to encourage heart rot. Preserving trees with mistletoe brooms will provide habitat for birds and small mammals; these areas typically have much higher species density.	Safer to work around live decadent trees than dead snags. Increased cost to create due to taller topping heights. Trees would need to be marked for protection during harvest. Decadent trees can be substituted for equivalent sizes of snags. Inoculation would provide cavities without killing the tree, thus maintaining a safer work area.
WHMP prescriptions call for dispersion of snags to meet an average distribution of 15 snags/5 acres.	Locate snags in clumps.	Use both small and large clumps. Retain live trees within these clumps.	Clumping reduces unsafe work area. Live trees included in clumps will help to retain shrubs and ground cover as well.

CURRENT PRACTICES	POTENTIAL RELEVANT ALTERNATIVE TECHNIQUES	IMPLEMENTATION DETAILS	BENEFITS
SNAG MANAGEMENT			
60-Year Rotation Stands (cont.):			
	Extend rotation to 80 years or greater.	Restructuring of harvest timing map to increase rotation age.	Fewer entries into units will result in less replacement of snags. Easier to produce larger snags in older stands; these will last longer than smaller snags.
	Created snags within harvest units can be shorter.	40' should be the minimum height.	Shorter snags will reduce hazardous work area.
Snags are currently managed on approximately 100 acre blocks to ensure adequate distribution of larger, less common snags across the landscape.	Establish several well-distributed large blocks of unmanaged lands to act as refugia for old-growth dependent species.	Incorporate adjacent harvest units to establish blocks of at least 100 acres.	The Lost Lake Tract and adjacent PMF currently totals 256 acres; the large OMA on the east side of Lake Chaplain is approx. 166 acres of old growth and adjoining second growth; the Horseshoe Bend area east of the river is approximately 130 acres, including the Gold Camp unit, which is currently comprised of high quality snags, CWD and decadent trees. This harvest unit should be removed from the managed inventory and added to this unmanaged block to provide continuity.

CURRENT PRACTICES	POTENTIAL RELEVANT ALTERNATIVE TECHNIQUES	IMPLEMENTATION DETAILS	BENEFITS
COARSE WOODY DEBRIS (CWD) MANAGEMENT			
Final harvest units: Provide 8 undecayed or Class 1 or 2 logs with avg. diameter of 20 in. and min. length of 20 ft. per acre. Douglas-fir preferred; hemlock acceptable.	Provide CWD inputs into 60-year rotation stands	Implement existing WHMP prescription, but provide large hemlocks and silver firs in addition to Douglas-fir.	Providing a greater variety of CWD species produces a range of decay classes over time, as different species decompose at different rates. Easier to find trees of suitable size if various species are selected.

CURRENT PRACTICES	POTENTIAL RELEVANT ALTERNATIVE TECHNIQUES	IMPLEMENTATION DETAILS	BENEFITS
DEER FORAGE MANAGEMENT			
Non-Harvest Stands			
Small patch cutting (< 1 ac.) allowed	Canopy gap creation		Canopy gaps promote shrub and herb layers in the midst of closed-canopy stands. The surrounding closed-canopy stands provide thermal cover.
60-Year Rotation Stands: Clearcutting	Aggregated green tree retention (GTR) and/or variable density thinning (VDT)		Aggregated GTR and thinning provide the immediate benefit of promoting shrub and herb layers, and the long-term benefits of promoting structural diversity.

CURRENT PRACTICES	POTENTIAL RELEVANT ALTERNATIVE TECHNIQUES	IMPLEMENTATION DETAILS	BENEFITS
RIPARIAN HABITAT, STREAMS AND WETLANDS			
Streamside buffer zones: 200 ft on Sultan R., 100 ft on Type 2 and 3 streams, 50 ft on Type 4 and 5 streams. Wetland buffer zones: 500 ft around Lost Lake and 200 ft around all other wetlands. Small patch cutting allowed in wetland BZ to promote understory development.	No alternative techniques proposed. On harvest units, compliance with Forest Practices rules is required. If the WHMP BZ is more restrictive than the FPA zone, the WHMP specification should be applied.		Reducing disturbance to forested wetlands and streams not covered under Forest Practices protects desirable shrub and herb layers, and wildlife species such as amphibians.
NEST STRUCTURE MANAGEMENT			
Current practice includes checking boxes near the end of July to avoid disturbing nesting birds.	Through careful observation of nesting activities and based on current literature, the peak of the local nesting season can be approximated to allow checks to be completed as follows.	Check nest boxes within 5 days of peak nesting period, add 1 to membrane count. Clean and repair boxes at the end of each nesting season.	Most of these details listed are not changes from the current management, but ensuring that checks are accurate and timely will increase the validity of the data.
Locations for placement of nest boxes is not specified by the WHMP		Place boxes inconspicuously & separate by 150' or more. Supply a minimum of 5/acre within 0.5 miles of wetlands.	

CURRENT PRACTICES	POTENTIAL RELEVANT ALTERNATIVE TECHNIQUES	IMPLEMENTATION DETAILS	BENEFITS
ROW MANAGEMENT			
Current management of the ROW entails mowing after the end of July and in the past has included use of nitrogen fertilizer.		<p>Continue use of late summer mowing to reduce seedling regeneration.</p> <p>Investigate use of biosolids application to amend soils and encourage grass and herb growth.</p>	<p>Biosolids will increase nutrient levels in the soil and reduce disposal costs for City of Everett.</p> <p>Control of noxious weeds before a full infestation occurs will reduce long-term control costs.</p>
Noxious weed control is not specified in the WHMP		Roadsides and portions of the ROW with noxious weeds should be mowed multiple times during the growing season to remove flowers and seed heads.	<p>Mowing in late summer allows grasses and forbs to seed naturally, reducing time and costs of spreading seed by hand.</p> <p>Late summer mowing also reduces likelihood that ground nesting birds and small mammal nests will be destroyed.</p>

Appendix 5

Stakeholders' Comments to Draft Technical Report

Message

Page 1 of 1

Presler, Dawn

From: Dustin Hinson [dhinson@stewardandassociates.com]
Sent: Friday, September 28, 2007 2:45 PM
To: Presler, Dawn
Cc: 'Cleve Steward'; jholton@stewardandassociates.com; 'Daryl Williams'
Subject: RE: Jackson Project (FERC No. 2157) - SP6 Habitat Methods DRAFT technical report for your review

Dawn,

Thank you for the opportunity to review the RSP6 habitat methods report. Our comments, on behalf of the Tulalip Tribes, are attached.

-Dustin

Dustin R. Hinson
Fisheries Biologist/Wetland Ecologist
Steward and Associates
120 Avenue A, Suite D
Snohomish, Washington 98290
360.862.1255
www.stewardandassociates.com

From: Presler, Dawn [mailto:DJPresler@SNOPUD.com]
Sent: Thursday, August 30, 2007 3:22 PM
To: deborah.knight@ci.sultan.wa.us; david.turner@ferc.gov; sonny.gohrman@co.snohomish.wa.us; Karen.suyama@snoqualmiation.com; karen1@snoqualmiation.com; Daryl Williams; csteward@stewardandassociates.com; dhinson@stewardandassociates.com; Tim_Romanski@fws.gov; dgray@fs.fed.us; arisvold@fs.fed.us; mkan461@ecy.wa.gov; jdra461@ecy.wa.gov; johnsrj@dfw.wa.gov; laurie.bergvall@dnr.wa.gov; Peter.McBride@dnr.wa.gov
Cc: Bedrossian, Karen; Moore, Kim; Julie Sklare
Subject: Jackson Project (FERC No. 2157) - SP6 Habitat Methods DRAFT technical report for your review

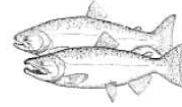
Dear Terrestrial Resources Group:
Please see attached RSP6: Habitat Methods Literature Review and Evaluation cover letter, draft technical report and appendices 1 and 2.

Comments on the draft report can be emailed or mailed to me by Sunday September 30, 2007 (email and mailing addresses are identified in the cover letter).

Dawn Presler
Relicensing Coordinator
Jackson Hydroelectric Project (P-2157)
Snohomish County PUD
Phone: 425-783-1709
Fax: 425-267-6369

10/16/2007

Steward and Associates
120 Avenue A, Suite D
Snohomish, Washington 98290
Tel (360) 862-1255 / Fax (360) 563-0393
www.stewardandassociates.com



Comments on

**Henry M. Jackson Hydroelectric Project
(FERC No. 2157)
Habitat Management Methods Literature Review and Evaluation Draft Final Report
August 30th 2007**

28 September 2007

The draft review and synthesis of available literature provides a very well written, thorough review of methodologies pertaining to the management of forested habitat communities. Incorporation of both relic best available science and cutting edge research will facilitate the development of a comprehensive strategy to manage these critical natural ecosystems. Specific comments are provided below:

Methodology review comments:

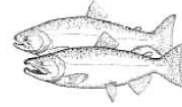
Section 1.0-Study Objectives and Descriptions

- This section is well written, good background, good description of HEP with specific quantifications of anticipated impacts from ongoing project work.

Section 2.0-Background Info: WHMP Management Techniques

- Section 2 is entitled "Techniques" but does not really describe techniques; this area provides strong quantitative and qualitative description of lands and waters and should possibly be renamed "WHMP Management Area Descriptions"?
- Table 2.0-1. Why are the wetlands associated with Lake Chaplain not listed as a management priority? If maintained and protected, they may be able to facilitate water quality, storage, and habitat improvements within the landscape.
- *Section 2.2-Streams, Wetlands, and Buffer Zones*
 - This section does not provide sufficient background regarding streams or wetlands. To better organize this section, the content should be split into two subsections: one outlining the background of the management techniques/status of streams and wetlands, and one focusing on the buffer zones of streams and wetlands.
 - Other pertinent information to add would include information describing the functions provided by wetlands and streams (habitat, wetlands erosion control, etc.), and additional functions of buffer zones other than just "provide edge and travel corridor" (vegetated buffers provide habitat, shade for stream, allochthonous inputs, etc.). This information should try to be as specific to the area as possible rather than just generalizations.
 - It is unclear as to what parameters are to be used to determine buffer zone widths and how were these parameters chosen. Reference further sections if appropriate to avoid redundancy if it is sufficiently explained later in the text.

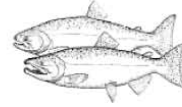
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Section 4.7-Riparian Habitat, Streams, and Wetlands

- 4.7.1 Definitions
 - This section provides an extensive well written definition of riparian habitat, a description of streams (not a definition), and no definition of wetlands. If it is to be assumed that wetlands are part of riparian habitat, it should be mentioned as such.
 - Strong description of the difference between RHA and riparian buffer.
- 4.7.2 Buffer Zones
 - Defined what parameters are used to determine Site Class.
 - Typo at bottom of page 46; third line up from bottom; should be “protected” not “protect”.
 - Include definitions of stream typing system S, F, Np and Ns.
 - Clarify why the amount of Np streams actually protected is dependent on the stream length.
 - Very clear definition of type A and B wetlands appears out of place in the buffer section. Potentially move this paragraph to the definitions section.
 - Good description of Snohomish County review of river processes, aquatic and riparian communities, and explanation of how the SPTH is used to assess buffer effectiveness. Clarify why microclimate and habitat function would require an SPTH of 3 and 3+, respectively as it is not apparent in the text.
 - Table 4.7.2-3 appears out of context and should be moved after description of stream types (paragraph 3).
 - Excellent description of FPA vs. GMA/County regulations/jurisdiction regarding standards for buffer zones.
 - Strong discussion of DOE rating system as basis for buffer.
 - Note that in addition to proving that a smaller buffer (due to buffer reduction) will protect the values and functions of a wetland, at least 1:1 mitigation should also be required as is noted in the Ecology BAS documentation.
 - Good, concise discussion of buffer increase due to T/E/S species; rather than defining a set increase in buffer, very appropriate and consistent with current practice to consult the appropriate County/WDFW biologist to discuss what the buffer should be given what type of sensitive wildlife are using the area.
 - Specify which version of the Snohomish County CAO referenced as they recently adopted a new ordinance (2007 or previous version).
- 4.7.3 Management of Riparian Areas, Streams, and Wetlands

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- Good discussion about forest management (specifically conifers) in riparian areas to promote habitat diversity and overall riparian area function.
- For completeness, the author may want to mention how to retain/manage hardwoods and scrub/shrub layers in addition to introducing/maintaining conifers to promote habitat diversity and increase diverse allochthonous inputs to streams (the focus of this review only discusses conifer introduction and management, mostly in relation to LWD).
- One of the goals discussed initially referenced emphasizes not only old growth and mature riparian forest in management plan, but young riparian forest as well. Later in the document, there is fairly minimal discussion of management techniques associated with young riparian systems.
- Readers did not observe any content within the report defining how to manage riparian wetland areas other than a reference that most existing documentation references restoration and mitigation practices in section 5.7.
- Other relevant discussion that did not appear in the review that should be noted is how to manage riparian areas to promote/increase connectivity to adjacent upland areas.

Section 5.7 Discussion: Application of Current Research to WHMP-Riparian Habitat, Streams, and Wetlands

- Well written summary of conclusions.
- The discussion indicates that WHMP does not prescribe active management of wetlands or buffer zones and that is potentially why it was not previously mentioned in this report; a discussion of the lack of information regarding active management of wetlands and buffers should be mentioned prior to this section so the reader has a better understanding as to the lack of content in these sections earlier in the report.

Appendix 1. Summary of literature review

- Readers found it difficult to track literature reference within the document to the appendices as the document cites numbers and not author names. The appendix is sorted by author last name within a section which makes it difficult to easily reference article summaries cited in the paper. Preferably, the references would be sorted by number within each section to allow readers to easily flip to the appropriate reference.

Appendix 2. Riparian Habitat Streams & Wetlands

- When clearing small patches to allow for understory development within wetlands, is there content within the FMP that specifies low impact techniques to minimize impact of machinery on these systems? Heavy equipment could compact soils, diminishing their ability to function at the same level as they did prior to the disturbance.

Presler, Dawn

From: Rich Johnson [JOHNSRJ@DFW.WA.GOV]
Sent: Wednesday, October 03, 2007 10:45 AM
To: Presler, Dawn
Cc: Bedrossian, Karen
Subject: Re: Jackson Project (FERC No. 2157) - SP6 Habitat MethodsDRAFT technical report for your review

To: Dawn Presler, Snohomish County PUD No. 1
SUBJECT: SP6 Draft Habitat Methods Technical Report

Staff of the PUD are to be commended for the effort put into producing this report. It is comprehensive, well organized, and provides a basis for informed decision making for the future terrestrial habitat management of the project lands. The report, and appendixes, meet WDFW's expectations of this study. We look forward to putting the findings to good use.

Rich Johnson
Habitat Biologist
Washington Department of Fish and Wildlife

Appendix 6

Responses to Draft Report Comments

STAKEHOLDER COMMENT	LICENSEE RESPONSE
Steward and Associates (Tulalip Tribes)	
<p>Section 1.0-Study Objectives and Descriptions</p> <p>This section is well written, good background, good description of HEP with specific quantifications of anticipated impacts from ongoing project work</p>	<p>No response required.</p>
<p>Section 2.0-Background Info: WHMP Management Techniques</p> <p>Section 2 is entitled “Techniques” but does not really describe techniques; this area provides strong quantitative and qualitative description of lands and waters and should possibly be renamed “WHMP Management Area Descriptions”?</p>	<p>Section 2 describes management techniques prescribed by the WHMP.</p>
<p>Section 2.0-Background Info: WHMP Management Techniques</p> <p>Table 2.0-1. Why are the wetlands associated with Lake Chaplain not listed as a management priority? If maintained and protected, they may be able to facilitate water quality, storage, and habitat improvements within the landscape.</p>	<p>Management priorities of the WHMP include wetlands (see Section 1.0, p.2.), and Table 2.0-1 lists wetlands as a characteristic of the Lake Chaplain Tract. Detailed management prescriptions for this tract call for protection of wetlands through designation of buffer zones.</p>
<p>Section 2.2-Streams, Wetlands, and Buffer Zones</p> <p>This section does not provide sufficient background regarding streams or wetlands. To better organize this section, the content should be split into two subsections: one outlining the background of the management techniques/status of streams and wetlands, and one focusing on the buffer zones of streams and wetlands.</p>	<p>Section 2.2 describes buffer zone requirements for wetlands and streams. The WHMP does not prescribe any other management activities for streams or wetlands.</p>
<p>Section 2.2-Streams, Wetlands, and Buffer Zones</p> <p>Other pertinent information to add would include information</p>	<p>These comments are very useful, but they go beyond the scope of this study. This information will be presented in the technical report for Revised Study Plan 9 – Wetland Surveys.</p>

STAKEHOLDER COMMENT	LICENSEE RESPONSE
describing the functions provided by wetlands and streams (habitat, wetlands erosion control, etc.), and additional functions of buffer zones other than just “provide edge and travel corridor” (vegetated buffers provide habitat, shade for stream, allochthonous inputs, etc.). This information should try to be as specific to the area as possible rather than just generalizations.	
<p>Section 2.2-Streams, Wetlands, and Buffer Zones</p> <p>It is unclear as to what parameters are to be used to determine buffer zone widths and how were these parameters chosen. Reference further sections if appropriate to avoid redundancy if it is sufficiently explained later in the text.</p>	Buffer zone widths in the WHMP were derived from Forest Practices standards, but were designed to exceed the standards that were in effect at the time the WHMP was written.
<p>Section 4.7.1 Definitions</p> <p>This section provides an extensive well written definition of riparian habitat, a description of streams (not a definition), and no definition of wetlands. If it is to be assumed that wetlands are part of riparian habitat, it should be mentioned as such.</p>	Good point. The section has been revised to summarize definitions from applicable statutes and regulations that apply to JHP lands. Many JHP wetlands are not riparian.
<p>Section 4.7.1 Definitions</p> <p>Strong description of the difference between RHA and riparian buffer.</p>	No response required.
<p>Section 4.7.2 Buffer Zones</p> <p>Defined what parameters are used to determine Site Class.</p>	Site Class determination is described in the Washington Forest Practices Manual.

STAKEHOLDER COMMENT	LICENSEE RESPONSE
<p>Section 4.7.2 Buffer Zones</p> <p>Typo at bottom of page 46; third line up from bottom; should be “protected” not “protect”.</p>	<p>Corrected.</p>
<p>Section 4.7.2 Buffer Zones</p> <p>Include definitions of stream typing system S, F, Np and Ns.</p>	<p>Definitions are extensively described in Forest Practices Rules WAC 222-16-030.</p>
<p>Section 4.7.2 Buffer Zones</p> <p>Clarify why the amount of Np streams actually protected is dependent on the stream length.</p>	<p>This review is not intended to be an exhaustive description of regulations or the rationale behind their formulation. Clarification of this rule can be found in the Forest Practices Rules WAC 222-30-021(2).</p>
<p>Section 4.7.2 Buffer Zones</p> <p>Very clear definition of type A and B wetlands appears out of place in the buffer section. Potentially move this paragraph to the definitions section.</p>	<p>The Forest Practices definition of wetlands does not differ from the definition used by other State, Federal and local jurisdictions. The classification of Forest Practices wetlands, however, is unique. This information was added to Section 4.7.1.</p>
<p>Section 4.7.2 Buffer Zones</p> <p>Good description of Snohomish County review of river processes, aquatic and riparian communities, and explanation of how the SPTH is used to assess buffer effectiveness. Clarify why microclimate and habitat function would require an SPTH of 3 and 3+, respectively as it is not apparent in the text.</p>	<p>The level of technical detail required to clarify this point goes beyond the scope of this review, which aims to briefly summarize current trends and findings in management.</p>
<p>Section 4.7.2 Buffer Zones</p> <p>Table 4.7.2-3 appears out of context and should be moved after description of stream types (paragraph 3).</p>	<p>Good point. The section has been revised to reflect this comment.</p>

STAKEHOLDER COMMENT	LICENSEE RESPONSE
<p>Section 4.7.2 Buffer Zones</p> <p>Excellent description of FPA vs. GMA/County regulations/jurisdiction regarding standards for buffer zones.</p>	<p>No response required.</p>
<p>Section 4.7.2 Buffer Zones</p> <p>Strong discussion of DOE rating system as basis for buffer.</p>	<p>No response required.</p>
<p>Section 4.7.2 Buffer Zones</p> <p>Note that in addition to proving that a smaller buffer (due to buffer reduction) will protect the values and functions of a wetland, at least 1:1 mitigation should also be required as is noted in the Ecology BAS documentation.</p>	<p>Good point. The section has been revised to reflect this comment.</p>
<p>Section 4.7.2 Buffer Zones</p> <p>Good, concise discussion of buffer increase due to T/E/S species; rather than defining a set increase in buffer, very appropriate and consistent with current practice to consult the appropriate County/WDFW biologist to discuss what the buffer should be given what type of sensitive wildlife are using the area.</p>	<p>No response required.</p>
<p>Section 4.7.2 Buffer Zones</p> <p>Specify which version of the Snohomish County CAO referenced as they recently adopted a new ordinance (2007 or previous version).</p>	<p>The revised version of SCC 30.62, which took effect on Oct. 1, 2007, is referenced in this review.</p>

STAKEHOLDER COMMENT	LICENSEE RESPONSE
<p>4.7.3 Management of Riparian Areas, Streams, and Wetlands</p> <p>Good discussion about forest management (specifically conifers) in riparian areas to promote habitat diversity and overall riparian area function.</p>	<p>No response required.</p>
<p>4.7.3 Management of Riparian Areas, Streams, and Wetlands</p> <p>For completeness, the author may want to mention how to retain/manage hardwoods and scrub/shrub layers in addition to introducing/maintaining conifers to promote habitat diversity and increase diverse allochthonous inputs to streams (the focus of this review only discusses conifer introduction and management, mostly in relation to LWD).</p>	<p>This is a good point, but the authors did not find applicable information in the literature to report on techniques for managing hardwoods and shrub layers in riparian zones. In fact, many references suggested that hardwoods and shrub communities are a problem because these vegetation types do not contribute as much large woody debris into streams as conifer-dominated communities. The WHMP supports the preservation of riparian hardwood communities by designated no-cut buffer zones.</p>
<p>4.7.3 Management of Riparian Areas, Streams, and Wetlands</p> <p>One of the goals discussed initially referenced emphasizes not only old growth and mature riparian forest in management plan, but young riparian forest as well. Later in the document, there is fairly minimal discussion of management techniques associated with young riparian systems.</p>	<p>See the preceding comment. The literature review did not turn up much applicable information on management or maintenance of young riparian forest. The WHMP emphasizes preservation of riparian habitat by avoiding disturbance.</p>
<p>4.7.3 Management of Riparian Areas, Streams, and Wetlands</p> <p>Readers did not observe any content within the report defining how to manage riparian wetland areas other than a reference that most existing documentation references restoration and mitigation practices in section 5.7</p>	<p>There is an extensive literature on the science of wetland mitigation. However, JHP wetlands are relatively undisturbed, and the WHMP protects them by means of buffer zones and avoiding impacts. The lengthy discussion of buffer zone widths in Section 4.7.2 is the most relevant information pertaining to management of JHP wetlands.</p>

STAKEHOLDER COMMENT	LICENSEE RESPONSE
<p>4.7.3 Management of Riparian Areas, Streams, and Wetlands</p> <p>Other relevant discussion that did not appear in the review that should be noted is how to manage riparian areas to promote/increase connectivity to adjacent upland areas.</p>	<p>This is a good point. Connectivity to upland areas is a frequent theme in the literature, but the authors did not find much specific information on how to accomplish this goal.</p>
<p>Section 5.7 Discussion: Application of Current Research to WHMP-Riparian Habitat, Streams, and Wetlands</p> <p>Well written summary of conclusions.</p>	<p>No response required.</p>
<p>Section 5.7 Discussion: Application of Current Research to WHMP-Riparian Habitat, Streams, and Wetlands</p> <p>The discussion indicates that WHMP does not prescribe active management of wetlands or buffer zones and that is potentially why it was not previously mentioned in this report; a discussion of the lack of information regarding active management of wetlands and buffers should be mentioned prior to the this section so the reader has a better understanding as to the lack of content in these sections earlier in the report.</p>	<p>This is a good point but how the techniques apply to the WHMP is the focus of Section 5. As stated in Section 4.0, the review focuses on methods that are applicable to the WHMP's goals and objectives. Many techniques that are in use elsewhere were not considered for this reason.</p>
<p>Appendix 1. Summary of literature review</p> <p>Readers found it difficult to track literature reference within the document to the appendices as the document cites numbers and not author names. The appendix is sorted by author last name within a section which makes it difficult to easily reference article summaries cited in the paper. Preferably, the references would be sorted by number within each section to allow readers to easily flip to the appropriate reference.</p>	<p>This is a good point, and an appendix has been added to simplify identifying literature references.</p>

STAKEHOLDER COMMENT	LICENSEE RESPONSE
<p>Appendix 2. Riparian Habitat Streams & Wetlands</p> <p>When clearing small patches to allow for understory development within wetlands, is there content within the FMP that specifies low impact techniques to minimize impact of machinery on these systems? Heavy equipment could compact soils, diminishing their ability to function at the same level as they did prior to the disturbance.</p>	<p>This is a good observation. Standard operating procedures for forest management under the WHMP call for use of low-impact equipment and logging techniques to avoid soil compaction.</p>
Washington Department of Fish and Wildlife	
<p>Staff of the PUD are to be commended for the effort put into producing this report. It is comprehensive, well organized, and provides a basis for informed decision making for the future terrestrial habitat management of the project lands. The report, and appendixes, meet WDFW's expectations of this study. We look forward to putting the findings to good use.</p>	<p>No response required.</p>

Appendix 7

Consultation Documentation

Date	Stakeholder	Consultation Type
4/30/2007	District to Terrestrial Resources Group	Email providing general update on study status.
05/04/2007	District to Terrestrial Resources Group	Email providing bibliography and requesting review and comments.
5/21/2007	District to Terrestrial Resources Group	Email reminder re: bibliography and requesting review and comments.
06/08/2007	District to Terrestrial Resources Group	Email providing annotated bibliography and requesting review and comments.
08/30/2007	District to Terrestrial Resources Group	Email providing draft technical report requesting review and comments.
09/28/2007	Steward and Associates (on behalf of the Tulalip Tribes) to District	Comments on draft technical report (see Appendix 5).
10/03/2007	WDFW to District	Comments on draft technical report (see Appendix 5).

Message

Page 1 of 3

Presler, Dawn

From: Bedrossian, Karen
Sent: Monday, April 30, 2007 5:46 PM
To: 'Rich Johnson'; 'Tim_Romanski@fws.gov'; 'Eric Ozog'; Kevin Buckley (kevin@snoqualmiation.com); Daryl Williams (dwilliams@tulaliptribes-nsn.gov); David Turner (David.Turner@ferc.gov)
Cc: Mixdorf, Glen; Meaker, Bruce; Julie Sklare; 'Tom Thetford'; Presler, Dawn; Marty Vaughn; 'KWSMAYDA@aol.com'; Doug Woodworth (dwoodworth@biotapacific.com); 'Nyman, Stephen'
Subject: Update on Terrestrial Resource Studies 6 through 12 for the Jackson Project (FERC 2157), April 30, 2007

Hello,

Below is a summary of the status of the relicensing terrestrial studies 6 through 12 for the Jackson Project (FERC 2157). Please contact Karen Bedrossian at kbedrossian@snopud.com by May 10, 2007, if you have any questions, comments, want to acquire additional information, or have any concerns. Also please let me know if you wish to have more participation in these studies. I will provide you with updates as the studies continue.

This update is to inform you of the current status of the studies identified in Revised Study Plans 6 through 12, being conducted as part of the relicensing process for the Jackson Hydroelectric Project. As indicated in the email you received on 3/27/07 from Dawn Presler, the co-licensees selected Biota Pacific Environmental Sciences, Inc. (Biota) to conduct Studies 7, 8, 11, and 12, and Devine Tarbell & Associates (DTA) to conduct Study 10. Contracts are now in place and work is being initiated. District biologists will be conducting Studies 6 and 9.

Study Plan 6 – Habitat Management Methods Literature Review and Evaluation:

District biologists Bernice Tannenbaum and Mike Schutt have this study well underway (see attached Study Plan 6 Summary and Schedule). They have compiled references and have started their review. Agencies and Tribes will be receiving a list of references this week that are being reviewed, so you can let us know if there are additional references that you think are relevant to this study.

Study Plan 7 – Special Status Plant Studies

Biota refined the schedule and is conducting the prefield review and developing the detailed survey plan (see attached study summary and schedule). The consultant, Kathy Smayda, will be contacting the US Forest Service botanist to review the list of plant species and survey locations.

Study Plan 8 – Noxious Weed Inventory

Biota refined the schedule and is conducting the prefield review and developing the detailed survey plan (see attached study summary and schedule). The consultant, Kathy Smayda, will be contacting the US Forest Service botanist to review the list of plant species and survey locations.

11/19/2007

Message

Page 2 of 3

Study Plan 9 – Wetland Survey

The District biologists conducting this study, Bernice Tannenbaum and Karen Bedrossian, attended a two day Coastal Training Program conducted by Thomas Hruby, for using the Revised Washington State Wetland Rating System for Western Washington where new refinements to the procedure were addressed. Evaluations will continue in the summer and as wetlands are identified adjacent to the Sultan River downstream of Culmback Dam during Study Plan 18.

Study Plan 10 – Amphibian Survey

DTA has conducted the first spring surveys. Species/egg masses found include northwestern salamander, roughskin newt, northern red-legged frog, bullfrog and Pacific treefrog. The consultant, Dr. Stephen Nyman, proposes to refine the study schedule (see the attached study summary, proposed survey schedule and survey timing discussion). He would like to move the fall survey to mid-September instead of October to early November. He advises that October may be too late and changing the schedule will provide more flexibility to make sure that the last survey of the year will be conducted at the most appropriate time. Please refer to the attachment for more details and let me know if you have any concerns with this. If not, we will go ahead and change the survey schedule.

Study Plan 11 – Marbled Murrelet Surveys

Biota has initiated work on this study and is in the process of identifying suitable habitat, establishing surveys stations and conducting surveys (see attached study plan summary and schedule). Given the difficulty of access, the biologists (Wayne Buck and team) may establish survey stations and conduct the surveys during the same site visit. If you are interested in reviewing the preliminary habitat assessment please contact Karen Bedrossian as soon as possible (no later than 5/10/07).

Study Plan 12 – Northern Spotted Owl Surveys

Biota has initiated work on this study and is in the process of identifying suitable habitat, establishing surveys stations and conducting surveys (see attached study plan summary and schedule). Given the difficulty of access, the biologists (Doug Woodworth and team) may establish survey stations and conduct the surveys during the same site visit. If you are interested in reviewing the preliminary habitat assessment please contact Karen Bedrossian as soon as possible (no later than 5/10/07).

Karen

Karen Bedrossian

Senior Environmental Coordinator

Snohomish County PUD

425 783-1774

11/19/2007

Presler, Dawn

From: Tannenbaum, Bernice
Sent: Friday, May 04, 2007 1:07 PM
To: Rich Johnson (johnsrj@dfw.wa.gov); Tim Romanski (Tim_Romanski@fws.gov); Eric Ozog (eozog@fs.fed.us); Daryl Williams (dwilliams@tulaliptribes-nsn.gov); David Turner (David.Turner@ferc.gov); Kevin Buckley (kevin@snoqualmiation.com)
Cc: Mixdorf, Glen; Bedrossian, Karen; Presler, Dawn; Julie Sklare (JSklare@ci.everett.wa.us)
Subject: Jackson Project (FERC #2157)

Dear Stakeholders,

Relicensing Study Plan 6 - Habitat Management Methods Literature Review and Evaluation - has been undertaken by District staff to identify advances in wildlife habitat management techniques that may be relevant and useful to the Jackson Project's Wildlife Habitat Management Plan (WHMP, 1988). A copy of Study Plan 6 can be found at the Jackson Project relicensing website:

http://www.snopud.com/Content/External/Documents/relicensing/Relicense/RSP/Revised_Study_Plan_091206_Modified.PDF



Bibliography.doc
 (480 KB)

To date, this review has identified a large number of technical studies, management plans and procedures that may be applicable to an evaluation of the WHMP's management techniques. Attached to this e-mail is a current listing of references from the scientific literature and staff's ratings of the relevancy of each reference to the goals and objectives of the WHMP and its management techniques. We request that you review this listing and identify by May 18, 2007 any additional important references, research results or management plans that you believe should be included. Please keep in mind that references regarding this study must be:

1. related to the Pacific Northwest ecosystem, i.e. western Oregon, Washington, British Columbia.
2. currently applicable, preferably dated after 1990.
3. consistent with the WHMP's stated goals and objectives, and relevant to the current management techniques. Review topics include:

- Old growth forest
- Riparian habitat
- Streams, wetlands and buffer zones
- Second growth forest/overstory management (including gaps and GTAs)
- Second growth forest/understory management
- Snags and gaps
- CWD
- ROW vegetation management
- Nest structures
- Deer forage

Additional references can be emailed to me at BRtannenbaum@snopud.com.

Future steps in Study Plan 6 will include the preparation of an annotated bibliography of references and a synthesis of the most appropriate techniques for implementing the WHMP.

Sincerely,

1

Bernice Tannenbaum
Environmental Coordinator
Snohomish Co. PUD
brtannenbaum@snopud.com
425-783-1746

Presler, Dawn

From: Tannenbaum, Bernice
Sent: Monday, May 21, 2007 2:26 PM
To: 'Rich Johnson'; 'Tim Romanski'; 'Eric Ozog'; 'Daryl Williams'; 'David Turner'; 'Kevin Buckley'
Cc: Mixdorf, Glen; Bedrossian, Karen; Presler, Dawn; 'Julie Sklare'
Subject: FW: Jackson Project (FERC #2157) – Wildlife Habitat Management Literature Review

Dear Stakeholders,

Earlier this month I e-mailed you a bibliography of references we are reviewing for Jackson Project Study Plan 6 - Habitat Management Methods Literature Review and Evaluation– and I requested your suggestions of additional reports, management plans, and other references that we might incorporate into our review of current methods. This is your opportunity to help us evaluate and improve the Jackson Project's terrestrial program, and I'd be glad to obtain your input into the process at this time. Please glance at the attached list of references (below) and send me your additions, which could include published and unpublished documents. If you're aware of someone doing research or management in any of our areas of interest that you think we should contact, we will include personal communications among the other references in the review. I'd appreciate having your responses by May 29, 2007

Thanks for your assistance,

Bernice Tannenbaum
brtannenbaum@snopud.com
 425-783-1746

-----Original Message-----

From: Tannenbaum, Bernice
Sent: Friday, May 04, 2007 1:07 PM
To: Rich Johnson (johnsrj@dfw.wa.gov); Tim Romanski (Tim_Romanski@fws.gov); Eric Ozog (eozog@fs.fed.us); Daryl Williams (dwilliams@tulaliptribes-nsn.gov); David Turner (David.Turner@ferc.gov); Kevin Buckley (kevin@snocalmiation.com)
Cc: Mixdorf, Glen; Bedrossian, Karen; Presler, Dawn; Julie Sklare (JSklare@ci.everett.wa.us)
Subject: Jackson Project (FERC #2157)

Dear Stakeholders,

Relicensing Study Plan 6 - Habitat Management Methods Literature Review and Evaluation - has been undertaken by District staff to identify advances in wildlife habitat management techniques that may be relevant and useful to the Jackson Project's Wildlife Habitat Management Plan (WHMP, 1988). A copy of Study Plan 6 can be found at the Jackson Project relicensing website:

http://www.snopud.com/Content/External/Documents/relicensing/Relicense/RSP/Revised_Study_Plan_091206_Modified.PDF



Bibliography.doc
 (480 KB)

To date, this review has identified a large number of technical studies, management plans and procedures that may be applicable to an evaluation of the WHMP's management techniques. Attached to this e-mail is a current listing of references from the scientific literature and staff's ratings of the relevancy of each reference to the goals and objectives of the WHMP and its management techniques. We request that you review this listing and identify by May 18, 2007 any **additional** important references, research results or management plans that **you believe should be included**. Please keep in mind that references regarding this study must be:

1. related to the Pacific Northwest ecosystem, i.e. western Oregon, Washington, British Columbia.
2. currently applicable, preferably dated after 1990.
3. consistent with the WHMP's stated goals and objectives, and relevant to the current management

techniques. Review topics include:

- Old growth forest
- Riparian habitat
- Streams, wetlands and buffer zones
- Second growth forest/overstory management (including gaps and reserve green trees)
- Second growth forest/understory management
- Snags and gaps
- CWD
- ROW vegetation management
- Nest structures
- Deer forage

Additional references can be emailed to me at BR.Tannenbaum@snopud.com.

Future steps in Study Plan 6 will include the preparation of an annotated bibliography of references and a synthesis of the most appropriate techniques for implementing the WHMP.

Sincerely,

Bernice Tannenbaum
Environmental Coordinator
Snohomish Co. PUD
brtannenbaum@snopud.com
425-783-1746

Presler, Dawn

From: Tannenbaum, Bernice
Sent: Friday, June 08, 2007 11:10 AM
To: Daryl Williams (dwilliams@tulaliptribes-nsn.gov); David Turner (David.Turner@ferc.gov); Eric Ozog (eozog@fs.fed.us); Kevin Buckley (kevin@snoqualmiation.com); 'laurie.bergvall@wadnr.gov'; Rich Johnson (johnsrj@dfw.wa.gov); Tim Romanski (Tim_Romanski@fws.gov); Cleve Steward; Dustin Hinson (dhinson@stewardandassociates.com); John Drabek (jdra461@ecy.wa.gov); Monika Kannadagali (mkan461@ecy.wa.gov); Peter McBride (Peter.McBride@dnr.wa.gov)
Cc: Bedrossian, Karen; Mixdorf, Glen; Schutt, Mike; Presler, Dawn; Julie Sklare (JSklare@ci.everett.wa.us)
Subject: Jackson Project (FERC #2157) --Wildlife Habitat Management Literature Review

Dear Stakeholders,

Relicensing Study Plan 6 - Habitat Management Methods Literature Review and Evaluation - was undertaken by District staff to identify advances in wildlife habitat management techniques that may be relevant and useful to the Jackson Project's Wildlife Habitat Management Plan (WHMP 1988). A copy of Study Plan 6 can be found at the Jackson Project relicensing website:

http://www.snopud.com/Content/External/Documents/relicensing/Relicense/RSP/Revised_Study_Plan_091206_Modified.pdf

District staff created a database listing a large number of technical studies, management plans and procedures that appeared to be applicable to an evaluation of the WHMP's management techniques, and rated the relevancy of each reference to the goals and objectives of the WHMP and its management techniques. To be selected for evaluation references had to be:

1. related to Pacific Northwest ecosystems, i.e. western Oregon, Washington, British Columbia.
2. currently applicable, preferably dated after 1990.
3. consistent with the WHMP's stated goals and objectives, and relevant to the current management techniques.

Review topics include:

- Old growth forests
- Riparian habitat
- Streams, wetlands and buffer zones'
- Second growth forest/overstory management (including gaps and reserve green trees
- Second growth forest/understory management
- Snags and gaps
- Coarse woody debris
- Right-of-way management
- Nest structures
- Deer forage

The list of references was sent to some of you in early May with a request that you review the citations and add any important references that you believe ought to be included in the evaluation.

Since then, District staff have added some citations to the database and summarized the information in the citations that we believe is relevant to the WHMP's objectives and management techniques. The annotated database is attached, and we request that you review the citations and our notes to ensure that we have included current information on habitat management techniques that you would like to see included in our evaluation of the WHMP. The next step in Study Plan 6 will include a synthesis, based on information in the annotated bibliography and information that you provide, of the most appropriate techniques for implementing the WHMP in the future.



Annotated
Bibliography to TRG .

I will be happy to receive your comments or additional references by email at brtannenbaum@snopud.com, or call me. Thanks for your assistance,

Sincerely,

Bernice Tannenbaum
Environmental Coordinator
Snohomish Co. PUD
brtannenbaum@snopud.com
425-783-1746

Message

Page 1 of 1

Presler, Dawn

From: Presler, Dawn
Sent: Thursday, August 30, 2007 3:22 PM
To: 'deborah.knight@ci.sultan.wa.us'; 'david.turner@ferc.gov'; 'sonny.gohrman@co.snohomish.wa.us'; 'Karen Suyama (Karen.suyama@snoqualmiation.com)'; 'karen1@snoqualmiation.com'; 'Daryl Williams'; 'csteward@stewardandassociates.com'; 'dhinson@stewardandassociates.com'; 'Tim_Romanski@fws.gov'; 'dgay@fs.fed.us'; 'arisvold@fs.fed.us'; 'mkan461@ecy.wa.gov'; 'jdra461@ecy.wa.gov'; 'johnsrj@dfw.wa.gov'; 'laurie.bergvall@dnr.wa.gov'; 'Peter.McBride@dnr.wa.gov'
Cc: Bedrossian, Karen; Moore, Kim; 'Julie Sklare'
Subject: Jackson Project (FERC No. 2157) - SP6 Habitat Methods DRAFT technical report for your review

Dear Terrestrial Resources Group:
Please see attached RSP6: Habitat Methods Literature Review and Evaluation cover letter, draft technical report and appendices 1 and 2.

Comments on the draft report can be emailed or mailed to me by Sunday September 30, 2007 (email and mailing addresses are identified in the cover letter).

Dawn Presler
Relicensing Coordinator
Jackson Hydroelectric Project (P-2157)
Snohomish County PUD
Phone: 425-783-1709
Fax: 425-267-6369

11/19/2007



Providing quality water, power and service at a competitive price that our customers value

August 30, 2007

Subject: Henry M. Jackson Hydroelectric Project (FERC No. 2157) –
Revised Study Plan 6: Habitat Management Methods Literature Review and Evaluation
Draft Technical Report for Review and Comment

Dear Terrestrial Resource Group:

The Jackson Project Relicensing Team is pleased to announce that the draft technical report for Revised Study Plan 6: Habitat Management Methods Literature Review and Evaluation is available for your review and comment. The draft technical report is attached. We hope that you will take this opportunity to review the report over the next 30-days and provide us with any comments or suggestions you might have prior to our posting of the final report to the relicensing web site. Please submit written comments, if any, by Sunday, September 30, 2007. Email comments to DJPresler@snopud.com or send via mail to:

Dawn Presler, E2
Snohomish County PUD
PO Box 1107
Everett, WA 98206-1107

Questions regarding the draft report can be directed to Karen Bedrossian, Senior Environmental Coordinator and Terrestrial Resources Lead, at (425) 783-1774 or KLBedrossian@snopud.com.

Thank you for your continued interest in the Jackson Project relicensing.

Sincerely,

Dawn Presler
Relicensing Coordinator
Jackson Hydroelectric Project
Phone: (425) 783-1709

cc: Relicensing files

2320 California Street • Everett, WA • 98201 / Mailing Address: P.O. Box 1107 • Everett, WA • 98206-1107
425-783-1000 • Toll-free in Western Washington at 1-877-783-1000 • www.snopud.com