

# **Snags and Down Wood in the Interior Columbia Basin Ecosystem Management Project<sup>1</sup>**

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## **Abstract**

Snags and down wood are major ecosystem and wildlife habitat components of the Interior Columbia Basin ecosystem. Their natural abundance and distribution have been altered by decades of land conversion, fire suppression, and timber and firewood harvest, but the degree and pattern of change have been open to question. Consequently, an analysis of the changes that have occurred was a required element of the Interior Columbia Basin Environmental Impact Statement. Members of the Science Advisory Group of the Interior Columbia Basin Ecosystem Management Project modeled snag and down wood abundance at the landscape level for the project analysis area. We constructed 10 density tables for combinations of 3 Potential Vegetation Groups, 2 temporal regimes, 2 fire regimes, and 2 public land management characterization classes. Snags and down wood were divided into two size classes, small and large, with a 53 cm DBH break point, and a 13 cm minimum DBH. Forest stands were placed into one of four categories: early-seral, mid-seral, late-seral single-strata, and late-seral multistrata. We defined five categories of snag and down wood abundance: none, rare, uncommon, common, and abundant. Each size class/abundance category combination, such as large snag/common, small down wood/rare, etc. had its own unique density range. We combined computer simulations using the Columbia River Basin Succession Model with geographic information system (GIS) data layers to project historical (pre-settlement) and current snag and down wood densities. We also made long-term (100 year) projections of snag and down wood trends based on the three public land management alternatives described in the Interior Columbia Basin Supplemental Draft Environmental Impact Statement. Our models for the Basin as a whole showed small and large snag abundances currently below the historical levels, and small and large down wood amounts currently greater than historical levels. The 100 year simulations projected small snag amounts returning to historical levels, large snag amounts increasing above current levels but not returning to historical amounts, and the small and large down wood amounts generally decreasing from current levels but remaining above historical levels.

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## Introduction

The Interior Columbia Basin Ecosystem Management Project, (ICBEMP), was established by charter in 1994. The charter, signed by the Chief of the USDA Forest Service (FS) and the Director of the Bureau of Land Management (BLM), provided instruction to the agencies to develop specific products that would lead to the adoption of a scientifically sound, ecosystem-based strategy for managing FS- and BLM-administered lands within the Interior Columbia Basin (ICB or "the Basin"). The charter also required the preparation of a Basin-wide Environmental Impact Statement (EIS). Quigley and Arbelbide (1997) developed an assessment of ecosystem components that described the ecological, social and economic conditions in the Basin. Two separate but complementary draft environmental impact statements (DEIS), known as the Eastside DEIS and the Upper Columbia River Basin DEIS (USDA Forest Service and USDI Bureau of Land Management 1997a, USDA Forest Service and USDI Bureau of Land Management 1997b), were prepared. Quigley and others (1997) developed a scientific evaluation of the management alternatives described in the DEIS documents. Subsequently, a supplemental draft environmental impact statement (SDEIS, USDA Forest Service and USDI Bureau of Land Management 2000) was issued to address public comments concerning the DEIS. Our work built from the landscape ecology portion (Hann and others 1997) of the assessment of ecosystem components (Quigley and Arbelbide 1997) and was part of an evaluation of long-term effects of the three management alternatives described in the SDEIS (USDA Forest Service and USDI Bureau of Land Management 2000).

The SDEIS contains three alternatives for the management of FS- and BLM-administered lands in the Basin. We will not describe them in detail here, but present a very brief summary of the key focus of each alternative (more detail is available at the Web site: <http://www.icbemp.gov>).

Alternative S1 is termed the "no action" alternative. The term "no action" does not mean that no management will take place. It means that management of FS- and BLM-administered public lands would continue based on the land use plans that are currently in place, including existing policies, U.S. Fish and Wildlife Service and National Marine Fisheries Service Biological Opinions, and Healthy Rangelands standards and guidelines. Analysis of a "no action" alternative is a requirement of the National Environmental Policy Act of 1976 (NEPA) and BLM and FS planning procedures.

Alternatives S2 and S3 are termed "action" alternatives that are meant to improve the clarity, focus, and ability to implement the proposed management direction. In general, the two action alternatives were designed to:

- Integrate landscape, disturbance regime, aquatic, terrestrial, socio-economic, and tribal components into one ecosystem management strategy;
- Protect important aquatic and terrestrial habitats;
- Identify priority areas for restoration; and
- Provide a link to existing management direction through a step-down process that will combine some land designations with management flexibility at the local level.

A key emphasis of alternative S2 is to minimize short-term risks, especially to threatened, endangered, or proposed species, important species habitats, and riparian

areas. The intent of the alternative is to put a greater emphasis on conducting detailed analysis prior to conducting management activities. Areas are prioritized for restoration in order to make management activities more effective and efficient.

Alternative S3, on the other hand, has a stronger emphasis on more quickly addressing long-term risks from either management activities or natural disturbance events; there is less of an emphasis on analysis. There is also a stronger focus on locating management activities where they can benefit isolated and/or economically specialized communities.

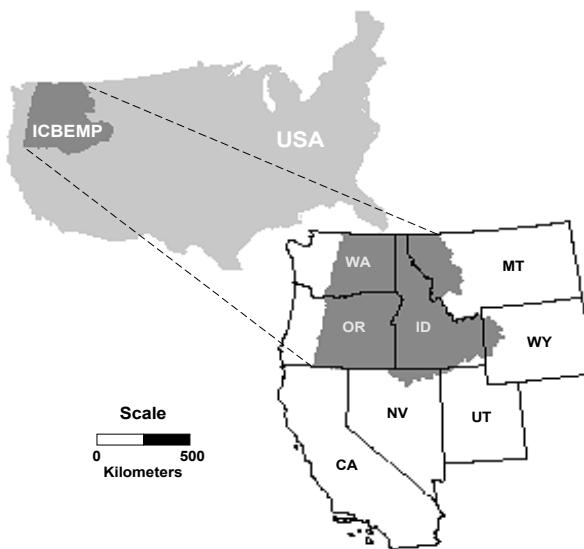
Snags and down wood are essential ecological components of the ICB ecosystem. Standing snags provide foraging, roosting, denning and nesting habitat for a number of wildlife species (Bull and others 1997, Marcot and others 1997, Thomas 1979, Wisdom and others 1999). As snags decay and fall to the ground, and become down wood, they provide food and shelter for different species (Bartels and others 1985, Maser and others 1979). Down wood also stores nutrients and moisture, and aids in soil development. Down wood in stream channels influences channel morphology; especially in forming pools and in-stream cover, retention of nutrients, and storage and buffering of sediment (Lee and others 1997).

Analysis of changes in snag and down wood densities across the Basin from historical times to the present may provide valuable insight into their management for the future. In this paper we describe the manner in which the snag and down wood abundance values were determined in the ICBEMP, their modeled current conditions in the Basin, and projected density trends after 100 years under three public land management alternatives.

## **Study Area**

The ICBEMP analysis area (*fig. 1*) covers approximately 58 million hectares (145 million acres) in the states of Washington, Oregon, Idaho, Montana, Wyoming, Nevada and Utah—an area approximately the same size as the country of France.

Public lands managed by the Forest Service and Bureau of Land Management account for 53 percent of the Basin. This represents approximately 25 percent of all FS-administered lands and 10 percent of all BLM-administered lands in the lower 48 states. Approximately 4 million hectares (10 million acres) in the Basin are federally designated wilderness, accounting for nearly one-third of all federally designated wilderness lands in the contiguous states. The study area also includes about 20 percent of the area in the lower 48 states that is American Indian reservation. The amount of timber harvested in the Basin accounts for approximately 10 percent of the total for the entire United States (Quigley and others 1996). Elevations in the Basin range from less than 150 meters to more than 3,000 meters above mean sea level. The average annual precipitation values are highly variable, and range from less than 20 to more than 250 centimeters per year (USDA Forest Service and USDI Bureau of Land Management 1997). More than 17,000 plant and animal taxa occur in the study area, including 609 known vertebrate taxa (Arbelbide and Quigley 1997). At present, the Basin contains 29 threatened or endangered species, including 16 fish species or species stocks.



**Figure 1**—The Interior Columbia Basin Ecosystem Management Project (ICBEMP) analysis area.

## Methods

### ***Snag and Down Wood Tables***

Members of the Science Advisory Group (SAG) formulated the snag and down wood density tables through an iterative process of literature review and discussions with experts. Our original tables, based on proposals put forward by the Environmental Impact Statement team, consisted of four forest stand classes (early-serial stands, mid-serial stands, late-serial single-strata stands, and late-serial multi-strata stands) and six Potential Vegetation Group (PVG)/land management combinations (e.g. Cold, Moist or Dry Forest, managed or unmanaged stands). Four tables, for current large and small snags and down wood, were constructed. We populated the 24 cells of each table with snag and down wood per-hectare values derived from the literature.

It quickly became apparent to us that the amount of usable data available from the literature was inadequate to populate most of the cells with values. We found that many published reports divided snags and/or down wood into size classes that could not be adapted to ours. Furthermore, many studies reported snag and down wood densities by vegetation types or age classes that we could not match. Differing units of measure were also a problem. For example, down wood amounts reported in square meters or tons per hectare could not be accurately converted to pieces per hectare. Attempts to fill the holes in the tables with values from the Forest Inventory Analysis (FIA) and Current Vegetation Survey (CVS) databases were ruled out due to the lack of comprehensive coverage.

Following discussions with snag and down wood experts and members of the EIS team we revised the format of the snag and down wood tables. The new format contained the same four forest succession/structure stages as before, but we now included a live tree component as a comparison to our snag and down wood amounts.

Live trees, snags, and down wood were all divided into small and large sizes. The small/large breakpoint was 53 centimeters (21 inches) diameter at breast height (DBH). “Small” did not include trees, snags, or down wood less than 13 centimeters (5 inches) DBH. These values were taken from the tree DBH size classes defined by Oliver (1981), modified by O’Hara and others (1996), and used throughout the CRBSUM modeling process (Keane and others 1996). The values were also commonly used in the literature on cavity nesting animals, particularly birds (Raphael and White 1984, Saab and Dudley 1998).

The new tables also used tree, snag, and down wood density categories instead of individual density values. The categories were none, rare, uncommon, common, and abundant. Each category represented a range of per-hectare values, and each forest component such as large snag, small down wood, etc. had its own definition for each category (e.g. “rare” for small live trees did not have the same value range as “rare” for large down wood). We also added two fire regimes (high-frequency low-intensity fires and low-frequency high-intensity fires) to the tables. There were 10 tables in all, covering 3 PVGs (Cold, Moist, and Dry Forest) 2 temporal regimes (historical and current), 2 fire regimes, and 2 management categories (unmanaged and managed):

1. Cold forest, historical conditions, low-frequency high-intensity fire regime;
2. Cold forest, historical conditions, high-frequency low-intensity fire regime;
3. Moist forest, current conditions, low-frequency high-intensity fire regime, unmanaged;
4. Moist forest, current conditions, low-frequency high-intensity fire regime, managed;
5. Moist forest, historical conditions, low-frequency high-intensity fire regime;
6. Moist forest, historical conditions, high-frequency low-intensity fire regime;
7. Dry forest, current conditions, low-frequency high-intensity fire regime, unmanaged;
8. Dry forest, current conditions, low-frequency high-intensity fire regime, managed;
9. Dry forest, historical conditions, low-frequency high-intensity fire regime;
10. Dry forest, historical conditions, high-frequency low-intensity fire regime.

We did not include managed conditions for cold forests because, for the most part, cold forests have not received extensive management and their fire regimes are relatively unaltered from historical conditions. The term “historical” refers to the conditions that existed prior to Euro-American settlement of the Basin. Historical and current live tree, snag, and down wood values were based on applicable literature values, expert opinion, and CRBSUM modeling. We submitted the revised tables to experts for review and held meetings to discuss the table attributes, our assumptions concerning density categories, snag and down wood dynamics, etc. before a final set of 10 tables was considered acceptable.

## Geographic Information Systems

Geographic Information System (GIS) modeling of the snag and down wood abundances across the Basin required a sequence of computations and data layer combinations that can be generalized into four major processes. First, the GIS team created a continuous Basin-wide vegetation layer at a one-kilometer scale. This layer was a combination of terrestrial community groups with dominant physiognomic types and potential vegetation groups for the historical, current, and simulated future conditions of the Basin (see Hann and others [1997] and Keane and others [1996] for a detailed discussion on the treatment of vegetation in the ICBEMP). This layer provided the necessary baseline information on forest vegetation, including successional stage and stand structure. A subsequent combination of this layer with a layer describing ecological disturbances was then produced to add information on fire regimes.

In the second step, the GIS team combined the vegetation layers with a layer detailing the various management prescriptions defined for each of the proposed alternatives in the SDEIS. The resulting layer was the basis for different snag and down wood management scenarios and allowed comparison of snag and down wood levels under the SDEIS alternatives.

The third step linked the data from the snag and down wood tables constructed by the SAG with the vegetation layers described in step one. In this third step, the GIS team assigned both snag and down wood density categories and category midpoints to the vegetation data, and included the different management prescriptions and proposed SDEIS alternatives. The resulting layers provided data about snag and down wood amounts across the Basin for the historical, current, and long-term (100 year) conditions under three proposed management alternatives.

In the fourth step the GIS team calculated a weighted average of density per subwatershed (6th code Hydrologic Unit or HUC6 level) for small and large snags and down wood for the historical, current, and simulated 100-year conditions of the Basin. This step allowed the analysis and summation of snag and down wood amounts according to various political, management, and land ownership units.

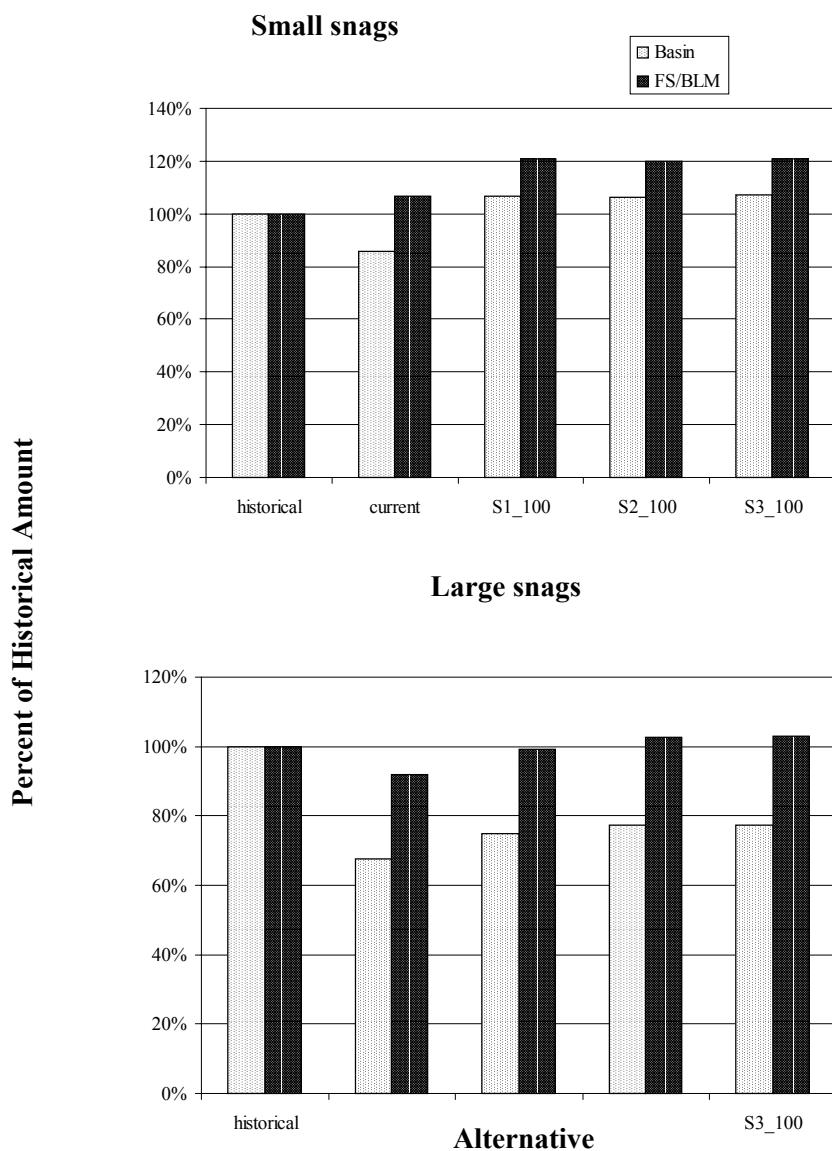
## Results and Discussion

Our results discussed are preliminary and subject to revision, as is the SDEIS document itself. All figures and maps are also draft documents and are subject to revision. We used snag and down wood amounts based on the vegetation in the historical scenario as the baseline for our comparisons. We present results for only the FS/BLM-administered lands and Interior Columbia Basin as a whole.

## Current Conditions

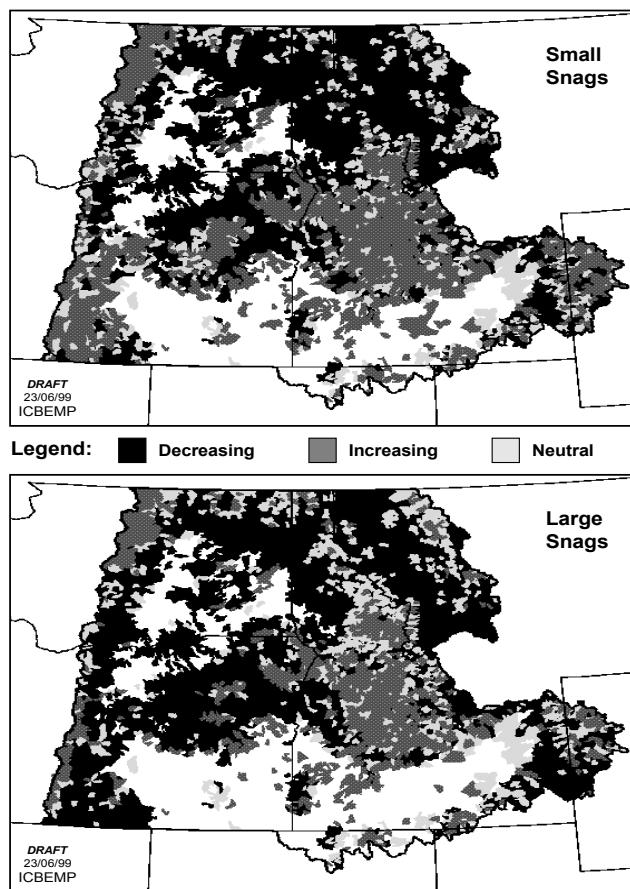
Our models indicated that small snag amounts increased slightly (7 percent) from the historical conditions on FS/BLM-administered lands but declined by 14 percent across the Basin (*fig. 2*). Most of the increase on FS/BLM lands occurred in the Dry Forest PVG, with some minor increases in the Cold Forest PVG. This occurred because the amount of forests in the mid-seral stage increased in the Dry Forest PVG, while the amount in the late-seral stage declined. In general, mid-seral stage forests contain fewer small snags per hectare than the late-seral forest,

especially in managed areas (Ohmann and Waddell, 2001). However, much of the increase in mid-seral forests on FS/BLM lands occurred in unroaded and wilderness areas. In these areas, fire suppression allowed development of dense stands of stressed, shade-tolerant trees having low resistance to insect and disease attack and, consequently, abundant small snags. Declines of small snags in the northern Rocky Mountains of Montana and Idaho and the foothills of the Cascade, Wallowa and Blue Mountains of Oregon (fig. 3) were more than offset by increases in much of central Idaho, the northern Cascade Mountains of Washington, portions of the southern Cascade, Wallowa, and Blue Mountains in Oregon, and in the Teton Mountains of Wyoming.



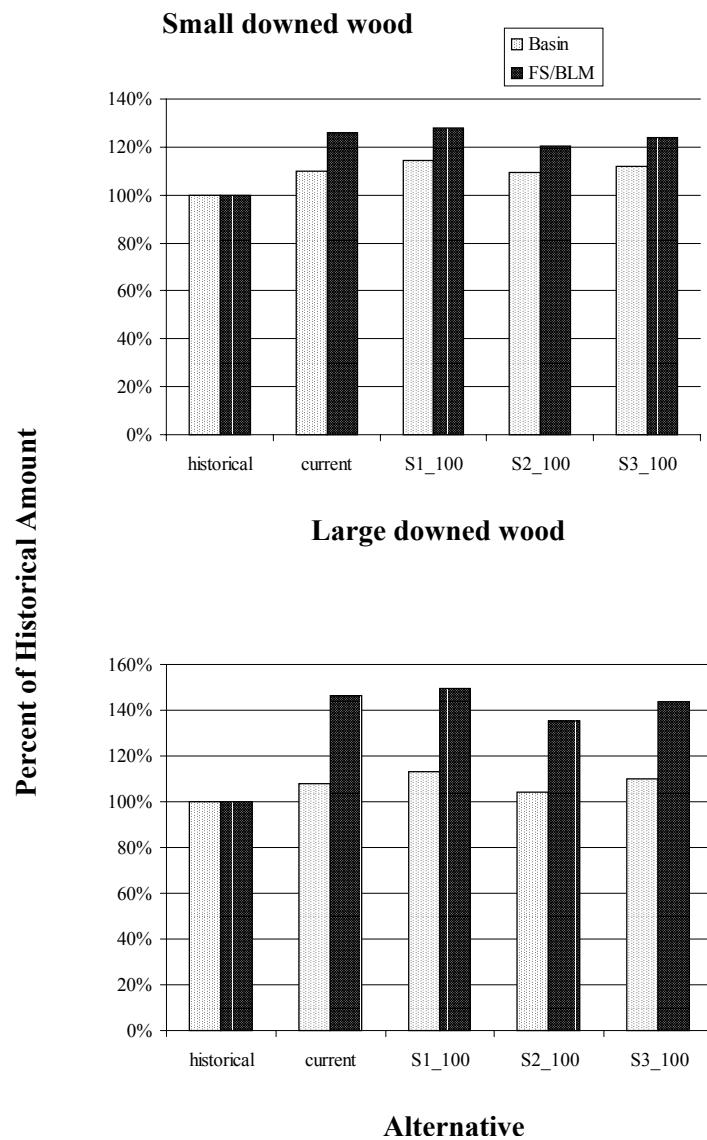
**Figure 2**—Small snag and large snag amounts as a percentage of the historical amounts for forest PVGs on FS/BLM ICBEMP lands and for the total Interior Columbia Basin. S1\_100, S2\_100 and S3\_100 represent the values after a 100-year simulation of the SDEIS management alternatives.

Large snag amounts declined by approximately 8 percent on FS/BLM-administered lands and 31 percent across the Basin, compared to the historical levels (fig. 2). The largest losses occurred in the Dry Forest and Moist Forest PVGs due to increases in mid-seral forests and decreases in late-seral forests. Late-seral stage forests typically contain higher levels of large snags. Large, fire-created snags may also be present in early-seral forests, but usually fall quickly. Few large snags remain standing into the mid-seral stage (Everett and others [In press]). There are generally fewer surviving large trees in early and mid-seral forests and, hence, reduced sources for new large snag recruitment. Furthermore, the new cohort of live trees does not become large enough to generate large snags until well into the mid-seral stage and often not until the late-seral stage. This may produce a "U-shaped" pattern of abundance described by Franklin and Spies (1991) similar to the "boom and bust" cycle discussed by Everett and others [In press]). Large snag declines on FS/BLM lands are compounded in managed or roaded areas by harvest and firewood cutting. The spatial pattern was very similar to that of the small snags; however, greater declines occurred in the Wallowa and Blue Mountains and the central and southern Cascade Mountains (fig. 3).



**Figure 3**—Current distribution of small snags and large snags trends across the Interior Columbia Basin. Neutral represents a value that is with 30 percent, positive or negative, of the historical level. Decreasing represents a decline of more than 30 percent, and increasing represents an increase of more than 30 percent. Unshaded areas represent non-forested lands.

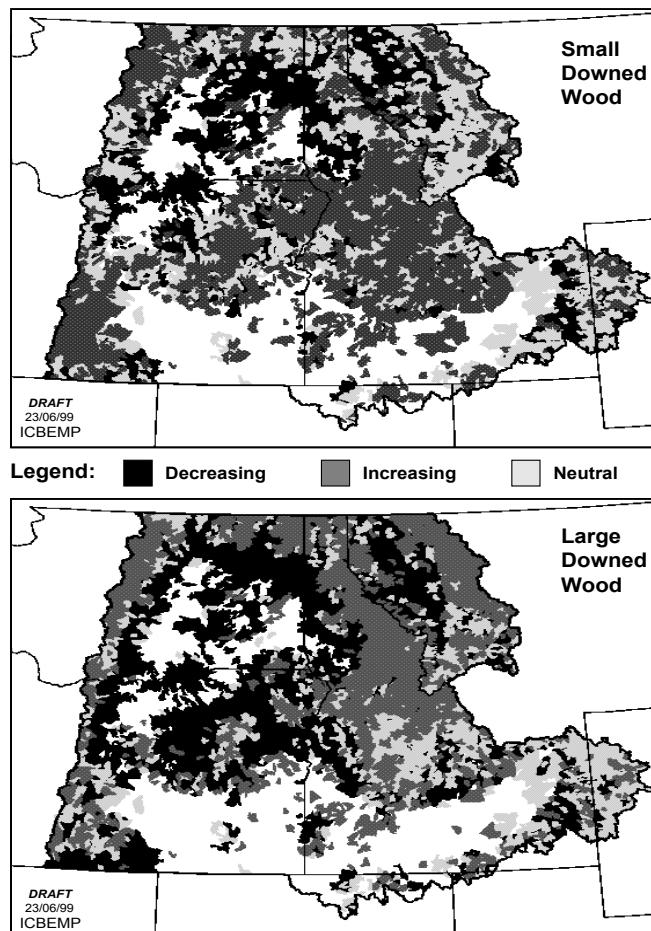
Small and large down wood amounts have increased from the historical levels on both FS/BLM-administered lands and across the Basin (fig. 4). In general, down wood has a longer 'life-span' than snags (Bartels and others 1985, Beukema and others 1999, Cline and others 1980, Lambert and others 1980, Maser and others 1979, Parks and Shaw 1996, Spies and others 1988, Stevens 1997,1999). The large numbers of trees killed by fires in the early- to mid-1900s generally are no longer present as snags, but are often present as down wood. Fire suppression often results in over-dense stands prone to insect and disease outbreaks. These conditions favor the recruitment of smaller down wood since small trees are more numerous than large trees and small snags usually fall sooner than large snags (Beukema and others 1999,



**Figure 4**—Small down wood and large down wood amounts as a percentage of the historical amounts for forest PVGs on FS/BLM lands and for the entire Interior Columbia Basin. S1\_100, S2\_100, and S3\_100 represent the values after a 100-year simulation of the SDEIS management alternatives.

Bull 1983, Bull and others 1980, Cline and others 1980, Everett and others in press, Huggard 1997, Morrison and Raphael 1993, Neitro and others 1985, Raphael and Morrison 1987, Raphael and White 1984). Large down wood pieces tend to last longer, however, perhaps resulting in similar increases over time.

Small down wood amounts increased from the historical levels by 25 percent on FS/BLM lands and about 10 percent across the Basin (*fig. 4*). In both cases, the increases occurred mostly in the Dry Forest PVG because of large increases in mid-seral stage forests. Although the mid-seral forests usually do not contain as much small down wood as the late-seral forests, the increase in the area of dense, over-crowded mid-seral forests generated by fire suppression produced abundant small down wood on FS/BLM lands, especially in unroaded and wilderness areas. Most of the increases took place in central Idaho, Washington's north Cascade Mountains, and Oregon's south Cascade, Wallowa, and Blue Mountains (*fig. 5*). Declines occurred in small areas, especially in east-central Washington (the southern Selkirk Mountains), along the central Oregon/Washington border, and in far northwest Montana (the Salish and Purcell Mountains).



**Figure 5**—Current distribution of small down wood and large down wood trends across the Interior Columbia Basin. Neutral represents a value that is with 30 percent, positive or negative, of the historical level. Decreasing represents a decline of more than 30 percent, and increasing represents an increase of more than 30 percent. Unshaded areas represent non-forested lands.

Amounts of large down wood increased substantially from historical levels on FS/BLM lands and, to a lesser extent, Basin-wide (*fig. 4*). In both cases, the greatest increases occurred in the Moist Forest PVG. Large down wood pieces can be very long-lived. Large snags created by fire, insect and disease attack often fall within 10 to 30 years (Bull 1983, Harrington 1996, Keen 1929, Lyon 1977, Mitchell and Preisler 1998, Schmid and others 1985), though some may last much longer (Hillis 1999 personal communication). This means that large down wood amounts are generally greater than large snag amounts in the late-serial stage (Ohmann and Waddell 2000). Increases in large down wood levels on FS/BLM lands are most likely due to a larger proportion of acres in non-roaded and wilderness areas where there is less removal of large down wood and large snags. The increases were found throughout much of central and northern Idaho, northwest Montana, northeast Washington, and the northern and southern Cascade Mountains (*fig. 5*). Areas that exhibited declines in large down wood amounts included northwest Montana, much of the Washington and Oregon Cascade foothills, the lower elevation forests of northeast Washington, and the mid and lower elevation Blue and Wallowa Mountains in Oregon. Only a few areas of south-central Idaho and northeast Wyoming showed no change.

### ***Long-Term Future Conditions***

Both small and large snag levels increased above current levels under all SDEIS management alternatives (*fig. 2*). Small snag levels increased by about 10 percent above current conditions on FS/BLM lands after 100 years under all three alternatives. The largest increase (for all alternatives) was in the Moist Forest PVG where the amount of late-serial stage forest increased greatly in all simulations. This increase was driven by the successional transition of large amounts of mid-serial to late-serial stage forests over 100 years. Small snags are common in the late-serial forests and amounts will continue to increase as succession progresses. Across the Basin, small snags increased beyond the current level, and exceeded the historical level after 100 years.

Large snags increased above the current level on both FS/BLM lands and across the Basin (*fig. 2*). Large snag abundance also reached or exceeded the historical level on FS/BLM-administered lands under all three alternatives. Across the Basin, large snags increased by 6 to 10 percent above the current level for all three alternatives, but remained about 75 percent of the historical amount. The major difference between alternatives was in the Dry Forest PVG where alternative S1 generated more mid-serial than late-serial forest. Alternatives S2 and S3 restored more late-serial forests in the Dry Forest PVG, consequently producing higher snag levels.

Small down wood increased very slightly on FS/BLM-administered lands under alternative S1, but decreased by several percent under S2 and S3 after 100 years (*fig. 4*). Most of the declines were in the Dry Forest and Moist Forest PVGs where decreases in the amounts of mid-serial forest were roughly balanced by increases in the late-serial and early-serial stages. Alternatives S2 and S3 include management measures designed to decrease fuel loads. The declines in small down wood amounts largely reflected those effects. Small down wood amounts remained nearly constant, or increased slightly, for all three alternatives at the Basin level, reflecting less aggressive fuels reduction efforts on non-FS/BLM lands.

Large down wood amounts followed a pattern similar (*fig. 4*) to that of small down wood across the Basin. Amounts increased slightly on FS/BLM-administered lands under alternative S1, but decreased under alternatives S2 and S3. Fuel reduction efforts in both alternatives S2 and S3 should reduce large down wood amounts in actively managed areas. This trend should be offset to some degree by large increases in dense late seral forest in unroaded and wilderness areas, generating large down wood levels far above historical conditions in those areas. At the Basin scale, only alternative S2 resulted in a decline in large down wood, while alternatives S1 and S3 produced small increases. This also reflected the emphasis on fuel reduction on FS and BLM-administered lands under alternatives S2 and S3.

## Conclusions

Small snag amounts have declined from the historical level on FS/BLM lands, but remained at roughly the historical level for the Basin as a whole. Large snag amounts have declined on both FS/BLM lands and across the Basin. Amounts of small and large down wood have increased beyond the historical levels on FS/BLM lands and across the Basin. Current amounts of snags and down wood have been influenced by four major processes:

- Forest succession;
- Timber (and firewood) harvest;
- Fire suppression with its impacts on stand composition and structure;
- Natural snag and down wood dynamics, including recruitment, fall rates, and rates of decay.

Our 100-year simulations indicated a long-term return to historical amounts for small snags on both FS/BLM-administered lands and across the Basin, due mostly to the succession of large areas of mid-seral stage forests to the late-seral stage. Large snags should return to historical levels on FS/BLM lands, but remain at roughly 75 percent of the historical amount across the Basin. Both small and large down wood amounts should remain above historical levels on FS/BLM lands and across the Basin. In this case, the dynamics are most influenced by the succession of large areas of mid-seral forest to late-seral forest and the long-lived nature of down wood itself. Increased prescribed fire will likely reduce the future accumulation of large down wood on FS/BLM lands, especially under alternative S2, but levels across the Basin under alternative S2 should approach those of historical conditions.

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## References

Bartels, R.; Dell, J. D.; Knight, R. L.; Schaefer, G. 1985. **Dead and down wood material**. In: Brown, E. Reade, technical editor. 1985. Management of wildlife and fish habitats in

forests of western Oregon and Washington. Part 1—chapter narratives. Publication No. R6-F&WL-192-1985; 171-186.

Beukema, S.; Reinhardt, E.; Greenough, J.; Kurtz, W. A.; Crookston, N.; Robinson, D. 1999. **Fire and fuels extension: model description.** Unpublished draft supplied by author; 58 p.

Bull, E. L.; Twombly, A. D.; Quigley, T. M. 1980. **Perpetuating snags in managed mixed forests of the Blue Mountains, Oregon.** In: DeGraff, R. M., technical coordinator. Management of western forests and grasslands for nongame birds. Ogden, UT: Intermountain Research Station, Forest Service, U. S. Department of Agriculture; 325-336.

Bull, E. L. 1983. **Longevity of snags and their use by woodpeckers.** In: Davis, J. W.; Goodwin, G. A.; Ockenfels, R. A., technical coordinators. 1983. Proceedings of the symposium: Snag habitat management. Gen. Tech. Rep. GTR-RM-99. Fort Collins, CO: Rocky Mountain Research Station, Forest Service, U. S. Department of Agriculture; 64-67.

Bull, E. L.; Parks, C. G.; Torgersen, R. T. 1997. **Trees and logs important to wildlife in the Interior Columbia River Basin.** Gen. Tech. Rep. PNW-GTR-391. Portland, OR: Pacific Northwest Region, Forest Service, U. S. Department of Agriculture; 55 p.

Cline, S.; Berg, A. B.; Wight, H. M. 1980. **Snag characteristics and dynamics in Douglas-fir forests, western Oregon.** Journal of Wildlife Management. 44(4): 773-786.

Everett, R.; Lehmkuhl, J.; Schellhaas, R.; Ohlson, P.; Keenum, D.; Reisterer, H.; Spurbeck, D. [In press]. **Snag dynamics in a chronosequence of 26 wildfires on the east slope of the Cascade Range in Washington.** International Journal of Wildland Fire.

Franklin, J. F.; Spies, T. A. 1991. **Ecological definitions of old-growth Douglas-fir forests.** In: Aubry, K. B.; Carey, A. B.; Huff, M. H.; Ruggiero, L. F., technical coordinators. 1991. Wildlife and vegetation in unmanaged Douglas-fir forests. Gen. Tech. Rep. PNW-GTR-285. Portland, OR: Pacific Northwest Region, Forest Service, U. S. Department of Agriculture; 61-69.

Hann, W. J.; Jones, J. L.; Karl, M. G.; Hessburg, P. F.; Keane, R. E.; Long, D. G.; Menakis, J. P.; McNicoll, C. H.; Leonard, S. G.; Gravenmier, R. A.; Smith, B. G. 1997. **Landscape dynamics of the Basin.** In: Quigley, T. M.; Arbelbide, S. J., eds. An assessment of ecosystem components in the interior Columbia Basin and portions of the Klamath and Great Basins. Gen. Tech. Rep. PNW-GTR-405. Portland, OR: Pacific Northwest Region, Forest Service, U. S. Department of Agriculture; 337-1055.

Harrington, M. G. 1996. **Fall rates of prescribed fire-killed ponderosa pine.** Ogden, UT: Intermountain Research Station, Forest Service, U. S. Department of Agriculture; 7 p.

Hillis, M. 1999. Forest Wildlife Biologist, Lolo National Forest. Personal communication.

Huggard, D. 1997. **Fall-down rates of subalpine fir snags at Sicamous Creek: implications for worker safety and habitat supply.** British Columbia Ministry of Forests Research Program. Extension Note No. 16; 6 p.

Keane, R. E.; Long, D. G.; Menakis, J. P.; Hann, W. J.; Befins, C. D. 1996. **Simulating course-scale vegetation dynamics using the Columbia River Basin Succession Model-CRBSUM.** Gen. Tech. Rep. INT-GTR-340. Portland, OR: Pacific Northwest Region, Forest Service, U. S. Department of Agriculture; 51 p.

Keen, F.P. 1929. **How soon do yellow pine snags fall?** Journal of Forestry 53: 735-737.

Lambert, R. L.; Lang, G. E.; Reiners, W. A. 1980. **Loss of mass and chemical change in decaying boles of a subalpine balsam fir forest.** Ecology 61(6): 1460-1473.

Lee, D. C.; Sedell, J. R.; Rieman, B. E.; Thurlow, R. F.; Williams, J. E.; Burns, D.; Clayton, J.; Decker, L.; Gresswell, R.; House, R.; Howell, P.; Lee, K.; MacDonald, K.; McIntyre, J.; McKinney, S.; Noel, T.; O'Conner, J.; Overton, C.; Perkinson, D.; Tu, K.; Van Eimeren, P. 1997. **Broadscale assessment of aquatic species and habitats.** In: Quigley, T. M.; S. J. Arbelbide, eds. An assessment of ecosystem components in the interior Columbia Basin and portions of the Klamath and Great Basins. Volume 111. Gen. Tech. Rep. PNW-GTR-405. Portland, OR: Pacific Northwest Region, Forest Service, U. S. Department of Agriculture; 1057-1496.

Lyon, L. J. 1977. **Attrition of lodgepole pine snags on the Sleeping Child Burn, Montana.** Res. Note INT-RN-219. Forest Service, U.S. Department of Agriculture; 4 p.

Marcot, B. G., Castellano, M. A.; Christy, J. A.; Croft, L. K.; Lehmkuhl, J. F.; Naney, R. H.; Nelson, K.; Niwa, C. G.; Rosentreter, R. E.; Sandquist, R. E.; Wales, B. C.; Zieroth, E.; 1997. **Terrestrial ecology assessment.** In: Quigley, T. M.; Arbelbide, S. J., eds. An assessment of ecosystem components in the interior Columbia Basin and portions of the Klamath and Great Basins. Volume 111. Gen. Tech. Rep. PNW-GTR-405. Portland, OR: Pacific Northwest Region, Forest Service, Department of Agriculture; 1497-1713.

Maser, C.; Anderson, R. G.; Cromack, K. Jr.; Williams, J. T.; Martin, R. E.; 1979. **Dead and down woody material.** In: Thomas, J. W., ed., Wildlife habitats in managed forests: the Blue Mountains of Oregon and Washington. Agric. Handb. 553. Washington, DC: U. S. Department of Agriculture; 78-95.

Mitchell, R. G.; Preisler, H. K. 1998. **Fall rate of lodgepole pine killed by the mountain pine beetle in central Oregon.** Western Journal of Applied Forestry 13 (1): 23-26.

Morrison, M. L.; Raphael, M. G.; 1993. **Modeling the dynamics of snags.** Ecological Applications 3(2): 322-330.

Neitro, W. A.; Binkley, V. W.; Cline, S. P.; Mannan, R. W.; Marcot, B. G.; Wagner, F. F. 1985. **Snags (wildlife trees).** In: Brown, E. R., technical editor. Management of wildlife and fish habitats in forests of western Oregon and Washington. Part 1—chapter narratives. Publication No. R6-F&WL-192-1985. Portland, OR: Pacific Northwest Region, Forest Service, U. S. Department of Agriculture; 129-169.

O'Hara, K. L.; Latham, P. A.; Hessburg, P.; Smith, B. 1996. **A structural classification of inland northwest forest vegetation.** Western Journal of Applied Forestry 11(3): 97-102.

Ohmann, J. L.; Waddel, K. L. 2001. **Regional patterns of dead wood in forested habitats of Oregon and Washington.** In: Laudenslayer, William F., Jr.; Shea, Patrick J.; Valentine, Bradley E.; Weatherspoon, C. Phillip; Lisle, Thomas E., technical coordinators. Proceedings of a symposium on the ecology and management of dead wood in western forests. 1999 November 2-4; Reno, NV. Gen. Tech. Rep. PSW-GTR-181. Albany, CA: Pacific Southwest Research Station, Forest Service, U.S. Department of Agriculture; [this volume].

Oliver, C. D. 1981. **Forest development in North America following major disturbances.** Forest Ecology and Management 3: 153-168.

Parks, C. G.; Shaw, D. C. 1996. **Death and decay: a vital part of living canopies.** Northwest Science (Special Issue) 70: 46-53.

Quigley, T. M.; Haynes, R. W.; Graham, R. T., technical editors. 1996. **Integrated scientific assessment for ecosystem management in the interior Columbia Basin and portions of the Klamath and Great Basins.** Gen. Tech. Rep. PNW-GTR-382. Portland, OR: Pacific Northwest Research Station, Forest Service, U. S. Department of Agriculture; 303 p.

Quigley, T. M.; Arbelbide, S. J., technical editors. 1997. **An assessment of ecosystem components in the Interior Columbia Basin and portions of the Klamath and Great**

**Basins.** Gen. Tech. Rep. PNW-GTR-405. Portland, OR: Pacific Northwest Research Station, Forest Service, U. S. Department of Agriculture; 1057 p.

Quigley, T. M.; Lee, K. M.; Arbelbide, S. J., technical editors. 1997. **Evaluation of EIS alternatives by the Science Integration Team.** Two volumes. Gen. Tech. Rep. PNW-GTR-406. Portland, OR: Pacific Northwest Research Station, Forest Service, U. S. Department of Agriculture; 1094 p.

Raphael, M. G.; Morrison, M. L. 1987. **Decay and dynamics of snags in the Sierra Nevada. California.** Forest Science 33(3): 774-783.

Raphael, M. G.; White, M. 1984. **Use of snags by cavity-nesting birds in the Sierra Nevada.** Wildlife Monograph No. 86; 66 p.

Saab, V. A.; Dudley, J. G. 1998. **Responses of cavity-nesting birds to stand-replacement fire and salvage logging in ponderosa pine/Douglas fir forests of southwestern Idaho.** Res. Paper RMRS-RP-11. Fort Collins, CO: Rocky Mountain Research Center, Forest Service, U. S. Department of Agriculture; 17 p.

Schmid, J. M.; Mata, S. A.; McCambridge, W. F. 1985. **Natural falling of beetle-killed ponderosa pine.** Res. Note RM-RN-454. Fort Collins, CO: Rocky Mountain Research Station, Forest Service, U. S. Department of Agriculture; 3 p.

Spies, T. A.; Franklin, J. F.; Thomas, T. B. 1988. **Coarse woody debris in Douglas-fir forests of western Oregon and Washington.** Ecology 69: 1689-1702.

Stevens, V. 1997. **The ecological role of coarse woody debris: an overview of the ecological importance of coarse woody debris in B.C. forests.** Research Branch, British Columbia Ministry of Forests, Victoria, British Columbia. Working Paper 30; 26 p.

Thomas, J. W., ed. 1979. **Wildlife habitats in managed forests: the Blue Mountains of Oregon and Washington.** Agric. Handb. 533. Washington DC: Forest Service, U. S. Department of Agriculture; 512 p.

U.S. Department of Agriculture, Forest Service, U.S. Department of the Interior, Bureau of Land Management. 1997a. **Eastside draft environmental impact statement.** 2 vols. BLM/OR/WA-PL-96-O37+1792. Portland, OR: Bureau of Land Management, U.S. Department of the Interior.

U.S. Department of Agriculture, Forest Service, U.S. Department of the Interior, Bureau of Land Management. 1997b. **Upper Columbia River Basin draft environmental impact statement.** 2 vols. BLM/ID-PT-96-021+1610. Boise, ID: Bureau of Land Management, U.S. Department of the Interior.

Wisdom, M. J.; Holthausen, R. S.; Wales, B. C.; Lee, D. C.; Hargis, C. D.; Saab, V. A.; Harm, W. J.; Rich, T. D.; Rowland, M. M.; Murphy, W. J.; Eames, M. R. 1999. **Source habitats for terrestrial vertebrates of focus in the Interior Columbia Basin: broad-scale trends and management implications.** Unpublished draft supplied by author.