In: Proceeding of the International Union of Forest Research Organizations World Congress; August, 1990; p.116-127.

1220

CURRENT KNOWLEDGE OF OLD GROWTH IN THE DOUGLAS-FIR REGION OF WESTERN NORTH AMERICA[1]

Thomas A. Spies

Research Forester
USDA Forest Service
Pacific Northwest Research Station
Corvallis, Oregon USA

FDC: 228.8: 180: (7-15)

SUMMARY

Old-growth forests in the Douglas-fir region of western North America have been the subject of considerable public debate and scientific research. Research efforts with regard to old-growth structure, function, habitat, dynamics and management are reviewed. New findings are revealing that old-growth structure varies widely across the region as a consequence of variation in disturbance and stand history. Most plant and animal species occur across the full range of stand development; however, several plant and animal species find optimum habitat in old-growth Douglas-fir stands. Different strategies are available for old-growth management on public lands.

Keywords: Forest development, structure, function

INTRODUCTION

Old-growth Douglas-fir forests once blanketed the mountains and valleys of many areas of the Douglas-fir Region of northwestern North America. Today much of this original forest condition is gone, for example, less than 20 % of the original area of old growth in western Washington and Oregon remains (Spies and Franklin 1988). The fate of the remaining stands is a subject of intense public debate at regional and national levels. Considerable research has been conducted in old-growth Douglas-fir forests in the last 20 years. Although many questions about the ecology of these forests remain, old-growth Douglas-fir is one of the most well-known old-growth types in the world.

---

[1] Portions of this paper are adapted from Spies and Franklin (1988).

The objectives of this paper are to review the current state of knowledge of old-growth Douglas-fir forests in western Oregon and Washington in terms of their structure, function, composition, and dynamics. Management options will then be discussed.

STRUCTURE

Considerable research has focused on identification of the structural components of old-growth Douglas-fir forests. Franklin et al. (1981) identified four major structures of old growth forests: live old-growth trees; standing dead trees or snags; fallen trees or logs on land; and logs in streams.

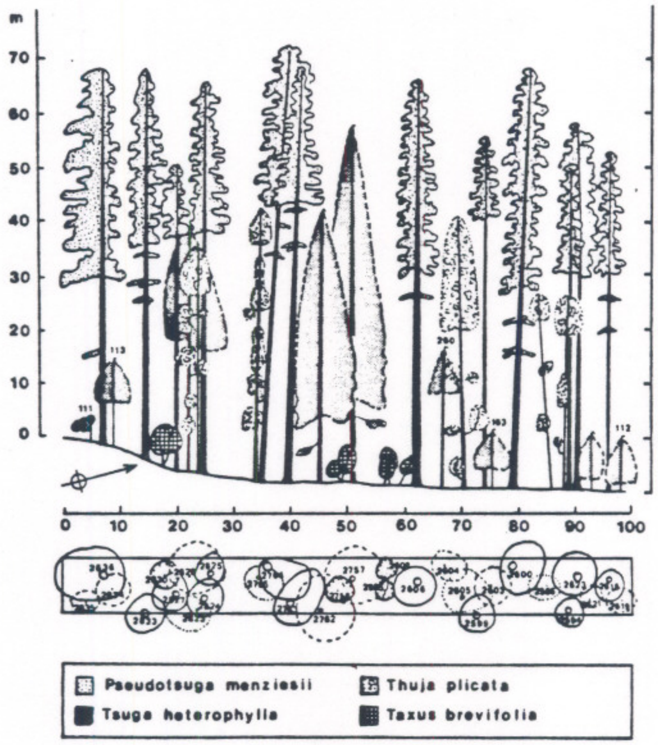

Figure 1. Vertical and horizontal structure of an old-growth Douglas-fir stand from the Oregon Cascade Range. (From Kuiper 1988)

Large old-growth Douglas-firs, and shade tolerant associates provide several unique habitat and functional roles. First, by virtue of their great height (Figure 1), more than 70 meters in many stands, the volume of the old-growth ecosystem is large, resulting in a diversity of environments and habitats from the canopy to the forest floor. Consequently, habitat is provided for many organisms including epiphytic lichens and mosses that grow on fan-shaped branches, bats and birds that feed on insects or use the branches for nesting, and animals that dwell in the cool moist understories. Many of the large trees have broken tops and cavities that provide nest sites for bird species. When the large trees die they leave large canopy openings that provide light to the understory that is valuable to the growth of understory trees and maintenance of populations of understory shrubs and herbs. Shade-tolerant trees--such as western hemlock, western redcedar and Pacific silver fir--are typically smaller in size than the seral Douglas-firs which are canopy emergents (Figure 1).

When canopy trees die they produce snags, which are abundant in all stages of Douglas-fir stand development (Spies et al. 1988). Large snags, more than 50 cm diameter and 15 m tall are most abundant in the first few decades after wildfire and in the old-growth stage. These large dead trees are valuable to cavity-excavating birds such as the pileated woodpecker (Dryocopus pileatus). The underside of sloughing bark also provides habitat for at least twelve vertebrate species (Brown 1985).

When live or dead trees fall to the forest floor they continue to function as important components of the ecosystem. Large, well-decayed logs, which are particularly common in old-growth forests, provide habitat to 150 or more species of vertebrate organisms and many hundreds of species of invertebrates (Brown 1985, Harmon et al. 1986). Large decayed Douglas-fir logs also provide germination sites of western hemlock and other plant species (Harmon and Franklin 1989). In forest streams, logs become habitat to vertebrates and invertebrates, trapping organic matter and storing inorganic sediments (Harmon et al. 1986).

Although many of the major structural components of old-growth Douglas-fir forests have been known for some time, only recently has any extensive quantitative analysis been conducted. Spies and Franklin (In press) examined over 200 unmanaged Douglas-fir stands from young to old growth. Discriminant analysis was used to evaluate variation in three age classes, young (40 to 80 years), mature (80 to 195 years), and old growth (195 to 900 years). Analysis of separate discriminant models based on different stand attribute sets, revealed that models based on overstory characteristics such as tree density, density of large Douglas-firs, and models based on overstory, understory, woody debris and stand conditions variables were most successful in distinguishing the age classes. Canonical variates analysis also indicated that best separation of the age classes was achieved by overstory attributes and a set of combined attributes. Considerable variation occurred in structure among the age classes. The age classes represented portions of a continuous gradient of structural variation that was associated with age.

Old-growth stands from different geographical provinces and relative site moisture classes varied considerably in structure. Much of the variation was associated with variation in densities of shade tolerant species and understory vegetation characteristics. Variation in old-growth structure across the region indicated that low to moderate levels of fire during the life of the stands had an important influence on stand structure.

FUNCTION

Gross primary production, the radiant energy fixed by photosynthesis per unit area of land, is maintained at high levels in old-growth Douglas-fir stands (Grier and Logan 1977). Net primary production (NPP), which is the gross primary production minus losses through plant respiration, is as high in old growth as in young Douglas-fir stands, although the form is different. In young stands most of the NPP is in biomass increment, but in old-growth tree mortality and litterfall constitute almost all of the NPP (Grier and Logan 1977).

Net wood production of Douglas-fir forests reaches a maximum by ninety years and can stay high for another 100 years, depending on site conditions, before declining (McArdle 1961). In an analysis of a thirty-six year record of gross and net growth in old-growth Douglas-fir (Debell and Franklin 1987), gross wood-volume growth was relatively high, but it was balanced by high tree mortality (Table 1). Net growth was minimal, and total stand volume stayed about the same.

Table 1. Cubic volume, growth, and mortality in cubic meters per hectare (1947-1983) by species for a 450 year-old *Pseudotsuga menziesii*/*Tsuga heterophylla* stand in the Cascade Range of Washington. (Adapted from DeBell and Franklin 1987)

Species	Volume (1947)	Gross growth	Mortality	Net growth
Pseudotsuga menziesii	547.9	79.6	107.1	-27.5
Tsuga heterophylla	254.7	116.8	59.8	+57.0
Abies spp.	58.8	26.9	16.7	+10.2
Other species	68.6	13.0	33.5	-20.5
Total	930.0	236.3	217.1	+19.2
Per annum		6.6	6.0	+0.5

Cycling of materials, an important component of ecosystem function, has not been well-studied in old-growth Douglas-fir forests. In general, nutrient losses from old-growth stands appear to be low (Sollins et al. 1980), although they may not differ much from young stands once canopy closure occurs (Cole et al. 1967). Where fog and low clouds are common, water yields from old growth may be up to 30 percent higher than in clearcuts because more water condenses and precipitates from the tall canopies with large amounts of surface area (Harr 1982). The age at which young forests intercept substaintial amounts of fog is not known.

HABITAT

Plant species diversity is typically higher in old-growth stands relative to younger closed canopy stages (Schoonmaker and McKee 1988, Spies In press). The highest plant diversity, however, occurs in very young stands following fire or clearcutting. Most plant species surveyed by Spies (In press) do not show a preference for old growth. However, at least 25 to 30 plant species appear to be more abundant and frequent in old-growth stands. For example, Taxus brevifolia, an understory tree, Tiarella trifoliata var unifoliata, an herb, and Lobaria oregana, a foliose canopy lichen, were all strongly associated with old growth in a survey of 177 stands of different ages (Spies In press).

Habitat associations of vertebrates with old-growth forests has received considerable attention in recent years. The most well-known case of a vertebrate species associated with mature and old-growth forests is the northern spotted owl (Strix occidentalis) (Forsman et al. 1984). This medium-size owl uses older forests for nesting, roosting, and foraging for its primary prey species, northern flying squirrels (Glaucomys sabrinus) and woodrats (Neotoma spp.). Because of the cutting of its habitat, without replacement, the spotted owl is currently being considered for listing as an endangered species protected under the Federal Threatened and Endangered Species Law.

Spotted owls are not the only species whose occurrence is associated with old-growth forests. A recently completed study of habitat relationships of salamanders, nongame birds, and small mammals (Ruggiero et al. In press) has turned up at least eight other vertebrates that are closely associated with old-growth forests in at least some portions of their ranges. Some 40 other vertebrates were found to be relatively more abundant in old growth than in earlier successional stages.

Many of the vertebrate species associated with old growth use specific old-growth structures such as decayed large logs, large dead standing trees or large live old tree crowns for hiding and breeding.

DYNAMICS

Coarse and fine scale disturbances have both played important roles in establishment, development, and destruction of old-growth Douglas-fir forests. Fire is the most frequent and widespread coarse-scale disturbance occurring at scales of 1 to > 10,000 ha. Recent research has demonstrated that the fire regime of the region is more complex than orginally thought. Initial research in Mount Rainier National Park in the Washington Cascades estimated fire return intervals of 400 to 500 years for large catastrophic fires (Hemstrom and Franklin 1982). More recent research in the central Oregon Cascades (Stewart 1986, Morrison and Swanson In press) paints a more complex picture that includes smaller, less severe, but more frequent fires. Morrison and Swanson (In press) found that fire return intervals varied between less than 100 years and over 150 years for fires of all intensities. Excluding low severity fires, the return intervals were over 200 years.

Currently several different scenarios of fire and forest development and succession are recognized for the region (Spies et al 1988, Morrison and Swanson In press). In one scenario, catastrophic fire kills all the trees in an old-growth stand, initiating establishment of Douglas-fir and some western hemlock seedlings. These stands develop for a long period without a subsequent stand-replacement fire, and develop old-growth structure around 150 to 250 years. Coarse woody debris follows a cycle of increase, decrease and increase over this 400 to 800 year period (Figure 2A).

In a second scenario, lower intensity fires kill only portions of the trees in a patchy manner. New tree establishment occurs in the burned patches, and the stand develops old-growth characteristics of various tree sizes and large dead trees sooner than it would in the first scenario. The cycle of woody debris does not reach the peaks and valleys of the first scenario (Figure 2B).

In a third scenario, fires recurr after the intial fire, and development of the forest is delayed. The repeat fires consume woody debris and delay the onset of old-growth conditions relative to the time since the initial fire. Woody debris cycles reach lower minimums in this scenario (Figure 2C).

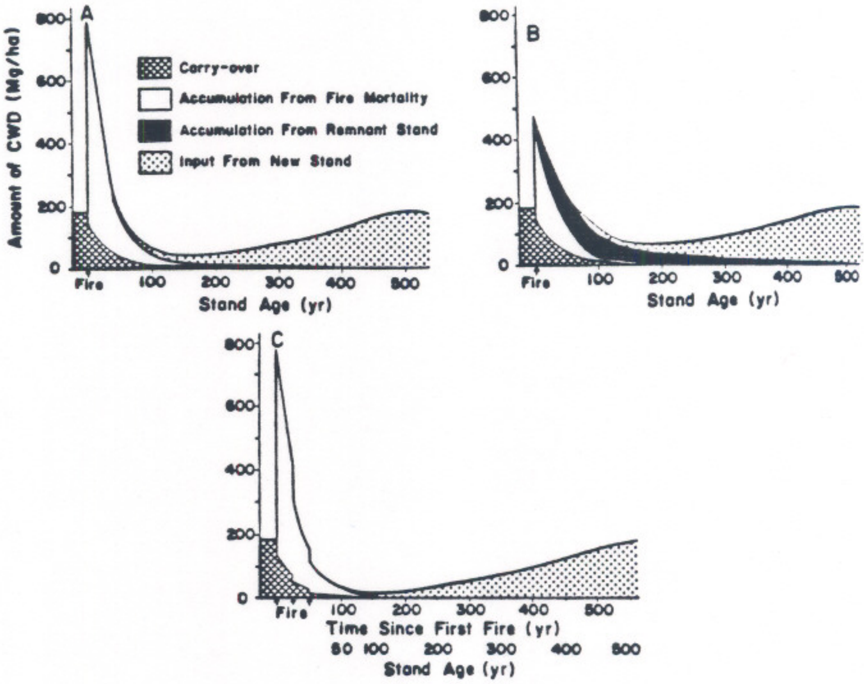

Figure 2. Predicted changes in coarse woody debris (CWD) mass following fire in a 450-yr-old Pseudotsuga-Tsuga forest: (A) catastrophic fire, (B) partial burn, (C) catastrophic fire and two subsequent fires 25 and 50 years later. CWD is divided into: present before the fire, produced by the fire, produced by the remnant stand, and produced by the stand growing after the fire (From Spies et al. 1988).

Several recent studies have identified that small-scale disturbances within old-growth stands are important to the dynamics of these forests. Franklin and Debell (1988) found that considerable mortality and replacement occurred over a 36-year period in 500 year old Douglas-fir/western hemlock forest. Annual rates of mortality were 0.75% but the mortality was balanced by recruitment of shade-tolerant tree species. Compositional changes were slow with exctinction of Douglas-fir predicted in 750 years at its current mortality rate. The importance of canopy openings to regeneration has been demonstrated by Stewart (1986) and Spies et al. (In press). Spies et al. (In press) found that gap formation rates were relatively low in old-growth Douglas-fir forests (0.2% of forest area per year), relative to other old-growth forest types (Runkle 1985). However, gaps were the primary sites of hemlock recruitment to the canopy. Spies et al. (In press) also found that many gaps were slow to fill. They attributed the slow vegetative response to gaps to the type of mortality events that created the openings. Over 70% of the old-growth canopy trees die without disrupting the forest floor (Spies et al In press, Franklin and DeBell 1988).

MANAGEMENT

Old-growth forests are of increasing interest to the public and land management agencies. Recently the U.S.D.A. Forest Service issued a new policy that recognizes old-growth as a valuable component of the National Forests. Management of old growth requires several steps. First, a definition of old growth is required that translates the ecological concept into one that managers can use in inventory, planning, and silviculture. Second, an inventory and map of current old-growth acreage is needed for each land ownership. Third, management alternatives need to be developed in terms of silvicultural systems that will maintain and create old-growth conditions at stand and landscape scales.

The first of these activities has been addressed through the development of interim definitions for old-growth Douglas-fir and mixed-conifer forests (Old-growth Task Group 1986). These definitions provide minimum standards for old-growth Douglas-fir stands in terms of structural features that can be measured in on-the-ground inventories.

While definitions are needed to answer questions about how much old growth exists and where it is located, such definitions must rely on somewhat arbitrary minimums that are used in classifying a stand as old growth or not. Many stands exhibit old-growth character but may lack a certain density of snags or large trees that would exclude them from the old-growth class. For broader management objectives such as wildlife habitat and biological diversity, such definitions will not be suitable. An index of structural diversity might be more appropriate (Spies and Franklin 1988) because it enables stands of all ages and management history to be characterized on the basis of how much they resemble some idealized old-growth reference point. Examples of some indices for old-growth Douglas-fir have been developed (Franklin and Spies In press).

Traditional U.S. Forest Service inventories have been based on timber objectives and consequently used tree size as a primary variable. Elements of old-growth structure, such as number of canopy layers and coarse woody debris, require additional information that has not typically been collected. In addition, many of the questions about old-growth habitat function require information about stand size and landscape context. Consequently, old-growth inventories must include maps. In the Douglas-fir region current inventory efforts are relying on LANDSAT imagery to map potential old-growth areas, and ground plots to evaluate attributes, such as woody debris, that can't be measured from remote sensing data. Current research efforts are focusing on how well canopy structure can be estimated from satellite imagery.

Current ideas of old-growth management span a range of activities from setting up old-growth reserves, to recreating old-growth characteristics on long rotations, to providing for individual structural components in young managed stands (Franklin et al. 1981). It is likely that all of these options will be exercised on public lands. However, the balance between them on a landscape scale is yet to be determined. Old-growth reserves are likely to be set up to provide habitat for the spotted owl. These reserves may be arrayed in a fashion that links them together with habitat corridors to facilitate owl movement between reserves.

Outside of old-growth reserve areas, management objectives on some lands may be to manage forests on long rotations (150 to 300 years) and to silviculturally manipulate young stands to reduce the time required to develop old-growth characteristics. Newton and Cole (1988) found that thinnings in young stands could shorten the time it takes to develop some old-growth characteristics such as large trees.

On some lands the objective might be to retain some old-growth structures in managed plantations to improve their habitat suitability. Under intensive forest management woody debris levels will be only a small fraction of that found in unmanaged stands (Spies and Cline 1988). Some large woody debris could be retained in managed forests by leaving large live trees and snags when old-growth stands are harvested. The retention and development of structural diversity in managed forests is a central focus of a call for new perspectives in forest management (Franklin 1989). Research on old-growth Douglas-fir ecosystems in the last 15 years has lead to a new appreciation of ecological diversity and is having a major influence on the direction that forest management will take in the Douglas-fir region.

CONCLUSIONS

Recent research has revealed that old-growth Douglas-fir forests are complex ecosystems that provide lessons for forest management. They are structurally distinct from younger forest stages, although many of the structural components survive natural disturbances and can be found in young stands. In many respects old-growth function and composition are similar to younger, unmanaged stands. However, old growth does represent a compositionally and functionally unique condition for several characteristics. Disturbance at coarse and fine scales has played an important role in the development and structure of old-growth Douglas-fir forests. Old growth is now recognized as a desirable management objective for many public lands in the region. The structure and dynamics of unmanaged Douglas-fir forests is providing new models for forest management at stand and landscape scales.

LITERATURE CITED

Brown, E.R., tech ed., 1985: Management of wildlife and fish habitats in forests of western Oregon and Washington. Part 1--chapter narratives. 332 p. Part 2--Appendices. 302 p. USDA Forest Service, Pacific Northwest Region, Portland, Oregon.

Cole, D.W., S.P. Gessel, and S.F. Dice., 1967: Distribution and cycling of nitrogen, phosphorus, potassium, and calcium in a second-growth Douglas-fir ecosystem. Pp. 197-223 in H.E. Young (editor), Primary production and mineral cycling in natural ecosystems. University of Maine Press, Orono.

DeBell, D.S. and J.F. Franklin., 1987: Old-growth Douglas-fir and western hemlock: a 36-year record of growth and mortality. Western Journal of Applied Forestry 2(4): 111-114.

Forsman, E.D., E.C. Meslow, and H.M. Wight., 1984: Distribution and biology of the spotted owl in Oregon. Wildlife Monographs 87(April): 1-64.

Franklin, J.F., K. Cromack, Jr., W. Denison, A. McKee, C. Maser, J. Sedell, F. Swanson, and G. Juday., 1981: Ecological characteristics of old-growth Douglas-fir forests. General Technical Report PNW-118, USDA Forest Service, Pacific Northwest Forest and Range Experiment Station, Portland Oregon. 48 p.

Franklin, J.F. and D.S. DeBell., 1988: Thirty-six years of tree population change in an old-growth Pseudotsuga-Tsuga forest. In press. Canadian Journal of Forest Research.

Franklin, J.F., 1989: Toward a new forestry. American Forests November/December: 37-44.

Franklin, J.F. and T.A. Spies., In press: Ecological definition of old-growth Douglas-fir forests. Pages XX-XX in L. F. Ruggiero, K.B. Aubry, A.B. Carey, and M.H. Huff, tech. coords. Wildlife and vegetation of unmanaged Douglas-fir forests. General Techical Report PNW-GTR-XXX, USDA Forest Service, Pacific Northwest Research Station, Portland, Oregon.

Grier, C.C. and R.S. Logan., 1977: Old-growth Pseudotsuga menziesii communities of a western Oregon watershed: biomass distribution and production budgets. Ecological Monographs 47(4): 373-400.

Harmon, M.E., J.F. Franklin, F.J. Swanson, P. Sollins, S.V. Gregory, J.D. Lattin, N.H. Anderson, S.P. Cline, N.G. Aumen, J.R. Sedell, G.W. Lienkaemper, K. Cromack Jr., and K.W. Cummins., 1986: Ecology of coarse woody debris in temperate ecosystems. Pp. 133-302 in A. MacFadyen and E.D. Ford, eds., Advances in ecological research, Vol. 15. Academic Press, Orlando, Florida, 302 p.

Harmon, M.E. and J.F. Franklin., 1989: Tree seedlings on logs in Picea-Tsuga forests of Oregon and Washington. Ecology 70(1): 48-59.

Harr, R.D., 1982: Fog drip in the Bull Run Municipal Watershed, Oregon. Water Resources Bulletin 18(5): 785-789.

Hemstrom, M.A. and J.F. Franklin., 1982: Fire and other disturbances of the forests in Mount Rainier National Park. Quaternary Research 18:32-51.

Kuiper, L.C., 1988: The structure of natural Douglas-fir forests in western Washington and western Oregon. Agricultural University Wageningen Papers 88-5. 47 p.

McArdle, R.E., 1961: The yield of Douglas Fir in the Pacific Northwest. USDA Techical Bulletin 201. 74 p.

Morrison, P.H. and F.J. Swanson., In press: Fire history in two forest ecosystems of the central western Cascade Range, Oregon. General Technical Report PNW-GTR-XXX USDA Forest Service, Pacific Northwest Research Station, Portland, Oregon.

Newton, M. and E. Cole., 1987: A sustained-yield scheme for old-growth Douglas-fir. Western Journal of Applied Forestry 2(2): 22-25.

Old-Growth Definition Task Group., 1986: Interim definitions for old-growth Douglas-fir and mixed-conifer forests in the Pacific Northwest and California. Research Note PNW-447. USDA Forest Service, Pacific Northwest Research Station, Portland, Oregon, 7 p.

Ruggiero, L.F., L.C. Jones, and Keith B. Aubry., In press: Plant and animal habitat associations in Douglas-fir forests of the Pacific Northwest: An Overview. in L. F. Ruggiero, K.B. Aubry, A.B. Carey, and M.H. Huff (tech. coords.), Wildlife and vegetation of unmanaged Douglas-fir forests. General Techical Report PNW-GTR-XXX USDA Forest Service, Portland.

Runkle, J.R., 1985: Disturbance regimes in temperate forests. Pages 17-34. in S.T.A. Pickett and P.S. White, (Edtiors), The ecology of natural disturbance and patch dynamics. Academic Press, New York, New York. 472 p.

Schoonmaker, P. and A. McKee., 1988: Species composition and diversity during secondary succession of coniferous forests in the western Cascade Mountains of Oregon. Forest Science 34(4): 960-979.

Sollins, P., C. Grier, F.M. McCorison, K. Cromack, R. Fogel, and R.L. Fredriksen., 1980: The internal element cycles of an old-growth Douglas-fir ecosystem in western Oregon. Ecological Monographs 50: 261-285.

Spies, T. and S. Cline. 1988. Coarse woody debris in forests and plantations of coastal Oregon. Pages 5-24. in C. Maser, R.F. Tarrant, J.M. Trappe and J.F. Franklin (Technical editors), From the forest to the sea: a story of fallen trees. General Technical Report PNW-GTR-229 USDA Forest Service, Pacific Northwest Research Station, Portland, Oregon. 153 p.

Spies, T.A. and J.F. Franklin., 1988: Old growth and forest dynamics in the Douglas-fir region of western Oregon and Washington. Natural Areas Journal 8(3): 190-201.

Spies, T.A. and J.F. Franklin., In press: The structure of natural young, mature and old-growth forests in Washington and Oregon. Pages xx-xx in L. F. Ruggiero, K.B. Aubry, A.B. Carey, and M.H. Huff (tech. coords), Wildlife and vegetation of unmanaged Douglas-fir forests. General Technical Report PNW-GTR-XXX, USDA Forest Service, Portland, Oregon.

Spies, T.A., In press: Plant species diversity and occurrence in young, mature, and old-growth Douglas-fir stands in western Washington and Oregon. in L. F. Ruggiero, K.B. Aubry, A.B. Carey, and M.H. Huff (tech. coords.), Wildlife and vegetation of unmanaged Douglas-fir forests. General Technical Report PNW-GTR, USDA Forest Service, Portland.

Spies, T.A., J.F. Franklin, and T.B. Thomas., 1988: Coarse woody debris in Douglas-fir forests of western Oregon and Washington. Ecology 69(6): 1689-1702.

Spies, T.A., J.F. Franklin, and M. Klopsch., In Press: Canopy Gaps in Douglas-fir forests of the Cascade Mountains. Canadian Journal of Forest Research.

Stewart, G.H., 1986: Forest development in canopy openings in old-growth Pseudotsuga forests of the western Cascade Range, Oregon. Canadian Journal of Forest Research 16(3): 558-568.

February 12, 1990