Characteristics of Log Resources in Northeastern Oregon: Case Studies of Four Management Treatments[1]

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Abstract

Logs have complex physical, biological, and functional attributes. The body of literature with detailed empirical data on log resources in diverse habitats in the Interior Columbia River Basin is sparse. Sampling schemes developed by the USDA Forest Service for assessing logs as woody fuel usually have translated amounts of logs into weight or volume per unit area (tons or ft^3 per acre). To depict amounts of logs in a more descriptive way—to assess wildlife habitat, for example—log resources may be more adequately described in terms of density, percentage cover, mean length, and combined length of logs per unit area, in addition to weight and volume. Sampling data are presented on log resources in the Blue Mountains of northeastern Oregon, which are compared to the standards set forth in the Pacific Northwest Regional Forester's Eastside Forest Plan Amendment No. 2, Alternative 2, for establishing riparian, ecosystem, and wildlife standards for timber sales. Data from four case studies are presented that characterize log resources in harvested and unharvested mid- and late-structure mixed conifer and ponderosa pine stands. Two case studies describe log resources in three stands before and after salvage harvest to reduce fuels, but maintain large-diameter logs. Post-salvage numbers of logs ($\geq$ 15 cm large-end diameter) per ha were 58 to 80 percent higher than pre-salvage densities. The proportion of large logs ($\geq$ 30 cm large-end diameter) among all logs remaining after salvage declined by 3 and 10 percent in two stands and increased 6 percent in one stand. Tonnage of logs increased by 4, 7, and 54 percent in the salvaged stands. Breakage of logs from felling and heavy equipment resulted in reductions in log lengths from about 8 m pre-salvage to 5 m post-salvage. Post-salvage amounts of log resources observed in all the harvested stands were generally higher than prescribed by the Eastside Forest Plan Amendment No. 2.

Introduction

Coarse woody debris (CWD) in all its forms has important physical, chemical, and ecological values in healthy forests. These values are well documented elsewhere in these proceedings (Laudenslayer and others 2002). However, what is largely unknown about CWD in general, or logs in particular, is how much is needed to support the complex of ecological functions dependent upon this stratum. A fundamental aspect of understanding ecological functions in a particular stratum such as logs is having the tools to quantify or otherwise describe that resource.

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Appropriate log sampling techniques must be able to cope with an array of variables over a wide range of densities and distributions, and that will describe the log resource in ways that have relevance to managers with a broad spectrum of bio-physical and socio-economic views of what a forest ecosystem should be or do. Because fire behavior and management are affected significantly by the abundance, distribution, and size characteristics of CWD, considerable energy has been devoted to portraying amounts of CWD as fire fuels (Brown 1974; Fischer 1981a, b; Koski and Fischer 1979; Maxwell and Ward 1976, 1980; Walstad and others 1990). Fuels specialists in the USDA Forest Service have typically described CWD in terms of tonnage (short tons) or volume (ft^3) per acre. But for the wildlife biologist who wants to assess log resources in ways that are relevant to wildlife, these two parameters are not very descriptive or useful. For example, tonnage is not a particularly relevant parameter for defining requirements for rodents whose numbers are related to percentage of the forest floor covered by CWD (Carey 2000, Carey and Johnson 1995, Wilson and Carey 2000). Similarly, quality of foraging habitat for pileated woodpeckers has been found to be related to density and size-class distribution, not tonnage, of logs in home ranges (Bull and others 1997, Torgersen and Bull 1995). Other forest professionals—mycologists, silviculturists, soil scientists, fire ecologists, economists, or logging engineers—will have their own views of useful descriptive parameters, and ways of looking at CWD as resource or risk.

With the broadening appreciation for the values of CWD, management is being called on to both quantify these resources, and to provide guidelines for its management in planning documents. In the Forest Service's Pacific Northwest Region, one such planning document is the Regional Forester's Eastside Forest Plan Amendment Number 2, Alternative 2. This directive was issued as a "Decision Notice for the Revised Continuation of Interim Management Direction Establishing Riparian, Ecosystem, and Wildlife Standards for Timber Sales" (Lowe 1995). The Decision Notice identified interim vegetative structural stages for ecosystem standards, and clarified wildlife standards (hereafter referred to as the "Standards") for nine National Forests on the east side of the Cascade Mountains in the Pacific Northwest. These Standards are being applied pending completion of an Eastside Ecosystem Management Strategy for the Pacific Northwest Region. A portion of the Decision Notice identifies the need for snags and down logs for wildlife nesting, roosting, and feeding. The Standards stipulate appropriate amounts and sizes of logs in specific stand types. *Table 1* shows the prescribed Decision Notice Standards, and their approximate metric equivalents, for ponderosa pine (*Pinus ponderosa* Dougl. ex Laws.), mixed conifers, and lodgepole pine (*P. contorta* Dougl. ex Loud.) stand types.

Embedded in these Standards are four terms for expressing amounts of log resources; three of which bear explanation. One of the implicit terms might be called "minimum log size." The Standards stipulate that logs under consideration in mixed-conifer and ponderosa pine stands shall be >6 feet long (1.8 m) and $\geq$12 inches (30.5 cm) in diameter at the small end. For convenience, such logs will be referred to here as "qualifying logs." The three explicit terms used to describe qualifying logs in the Standards are "diameter at small end," "total lineal length," and "pieces per acre."

Table 1—*Log standards as presented in the Regional Forester's Eastside Forest Plan, (Lowe 1995).*

Stand type	Pieces per acre	Diameter at small end	Piece length	Total lineal length
Ponderosa pine	3-6 (7-15 per ha)	12 in. (30 cm)	>6 ft. (2 m)	20-40 ft. (6-12 m)
Mixed conifer	15-20 (37-49 per ha)	12 in. (30 cm)	>6 ft. (2 m)	100-140 ft. (30-43 m)
Lodgepole pine	15-20 (37-49 per ha)	8 in. (20 cm)	>8 ft. (2.5 m)	120-160 ft. (37-49 m)

"Diameter at small end" may be misleading because it does not refer to the actual small end of the log. For example, given a ponderosa pine log that is 11 m long, 50 cm in diameter at its larger end, and 20 cm at its smaller end, the stipulated 30.5 cm (12 inches) "small end diameter" is not an "end" at all, but the place along the log's length at which the log is 30.5 cm. This is a relevant point in explaining the term—"total lineal length." First, only qualifying logs in terms of minimum piece-length and diameter can contribute to total lineal length. In the above example of the 11-m-long ponderosa pine log, only about 7.15 m would count toward its qualifying "lineal length" because only that much of the log is equal to or greater than the stipulated 30.5 cm "small end diameter." The sum of the qualifying lineal lengths[3] of individual logs in a stand or sampling unit contributes to "total lineal length" per acre. "Pieces per acre" is simply an expression of the number per acre of log pieces of the stipulated qualifying size.

Empirical data that present log resources in terms of the explicit log descriptors used in the above Standards are scarce. In fact, there are also no well-established sampling protocols for estimating either number of logs or their total lineal length per unit area. Computer outputs for Forest Service fuels inventories that are conducted with the line-intersect sampling protocols of Brown (1974) routinely express log resources as tonnage and weight, not in terms of density or total lineal length. To determine the parameters stipulated in the Standards, the line intersect sampling protocols would have to be expanded to include at least log lengths and large-end diameter (LED) of intersected logs. Log-taper factors for particular species of logs could then be used to calculate total qualifying lineal length of logs. If samplers added small-end diameter (SED) to the measurements collected during line-intercept sampling, then total lineal length could be calculated using one or more appropriate formulae.[3] But the point is that these additional measurements are not now routinely being collected.

[3] The amount of qualifying length (m) in a log may be calculated by using the following equation: QL = TL (BPD – LED / SED – LED); where QL is qualifying length of a log; TL is total log length; BPD is the qualifying break- point-diameter, e.g. 0.305 m (12 inches); LED is large end diameter; and SED is small end diameter of the log. All dimensions in meters. Example: If TL = 11m; BPN = 0.305m; LED = 0.50m; and SED = 0.20m; then QL = 7.15m.

The objectives of this paper are to describe log resources in selected mixed conifer and ponderosa pine stands, before and after treatment, under four management scenarios, and to compare this new information with the Standards for log retention as set forth in the Region 6 Decision Notice. For these comparisons I will use log resource descriptors from four case studies of selected stand types and treatments in northeastern Oregon: 1) in late-structure stands 40 years after selective harvest; 2) before and after salvage/fuel-reduction harvest; 3) before and after a fuel-reduction harvest to conserve late-structure large trees; and 4) after selection harvest and prescribed underburn.

Study Areas and Methods

The forest stands we examined are all in the Blue Mountain Province in northeastern Oregon. For the log inventories reported here, logs had to be ≥ 15 cm (6 inches) at their large end and ≥ 2 m (6.6 feet) long. For each log, whether in fixed-area plots or on transects, we recorded large-end diameter (LED) and small-end diameter (SED) to the nearest cm, and length to the nearest m. Decay class was tallied to determine weight of logs (Brown and See 1981). Smalian's formula (Wenger 1984) was used to compute volume. When line-intercept sampling was used (as in case study 4), the equations of DeVries (1973) were used to calculate log variables on a per ha basis.

Log resources are presented in terms of the traditional variables of volume and tonnage per unit area as used in fire fuels inventories. Density, mean length of logs, and total lineal length of logs per ha are presented because these are the variables stipulated in the Standards. Total lineal length of logs was obtained by first calculating the amount of qualifying length in each log,[3] and adding the qualifying lengths to obtain total lineal length per unit area. Although inventories of log resources do not routinely use density as an expression of measurement, this variable is used in the Standards and in some studies of wildlife use of logs (Bull and others 1995, 1997; Torgersen and Bull 1995). Percent cover of logs was added as a variable to describe log resources because of the wide use of this variable to describe habitat for small mammals (Buchanan and others 1999, Carey and Johnson 1995, Carey and others 1999, Wilson and Carey 2000). This variable is also referred to as projected area or projected cover (Caza 1993, Harmon and Cromak 1987, Marshall and others 2000).

Differences between log resources before and after salvage harvesting were tested using the t-test (SPSS software).[4]

Case 1—Late-structure Stands

Study stands were selected in the Five-Lock Forest Demonstration Area on the Umatilla National Forest about 20 km west of Ukiah, Oregon. Twelve stands were chosen to represent three stand types: 1) designated old-growth mixed conifers; 2) mid- to late-structure mixed-conifers; and 3) late-structure ponderosa pine. These stands were relatively natural, i.e., without recent harvest entries. The term "natural" for characterizing these stands is used advisedly because virtually all of the stands

[4] Mention of trade names or products is for information only and does not imply endorsement by the U.S. Department of Agriculture.

had some selective harvesting for the largest ponderosa pine and Douglas-fir about 40 years ago. Also, fire control would certainly have altered fire-return intervals compared with patterns existing prior to the time of European settlement in the 19th century. Each of the three stand types was represented by four study stands 5-12 km apart. Within each of the four 10-15 ha stands there were ten randomly located 20 x 20-m plots on which log inventories were conducted.

Case 2—Salvage/Fuel-reduction Harvests

One mixed-conifer stand each was located in the MacKay and Lane Creek drainages of the Wallowa-Whitman and Umatilla National Forests 30 and 50 km west of La Grande, Oregon. These 12 and 15 ha stands had mid- to late-structure Douglas-fir (*Pseudotsuga menziesii* [Mirib.] Franco) and grand fir (*Abies grandis* [Dougl. ex D.Don] Lindl.), with minor amounts of ponderosa pine and western larch (*Larix occidentalis* Nutt.). Both stands had suffered heavy defoliation in the course of a western spruce budworm (*Choristoneura occidentalis* Free.) outbreak from 1980-1992 (Scott and Schmitt 1996). The heavy mortality sustained in these two areas prompted District managers to prescribe salvage sales in 1996 to both reduce fuels and to maintain late and old structural components of large-diameter live and dead trees and logs. The prescription stipulated that only dead or dying trees with less than 50 percent live crown and < 38 cm (15 in.) dbh could be harvested. Large logs with the same minimum large end diameter were also to be left. In 1994, we did a comprehensive pre-salvage log inventory in each of the stands. We sampled 20 and 30 randomly distributed 10 x 10-m plots at the Lane and MacKay stands, respectively. In 1996, we conducted a post-salvage inventory on the same plots to characterize changes in log resources. In each plot, we measured all logs with a large-end diameter (LED) $\geq$15 cm, a minimum length of 2 m, and whose mid-length-point lay within the plot boundaries.

Case 3—Fuel-reduction Harvest to Retain Old-growth Characteristics

This site was at Frog Heaven on the Umatilla National Forest about 42 km southwest of La Grande. This stand was the subject of a study reported by Bull and others (1995), in which the management objective was to protect old, large-diameter living and dead stems by lowering fire risk, and to encourage regeneration. The study was laid out within harvest units designed to examine the effects of a fuel-reduction treatment to protect late-structure stands that had a heavy component of large trees. There were several large trees in these stands that were nesting or roosting trees for pileated woodpeckers *(Dryocopus pileatus)* and had been used for several years by nesting Vaux's swifts *(Chaetura vauxi)*. The stand had sustained repeated heavy defoliation by the western spruce budworm during a local outbreak from 1980-1992 (Scott 2000). Mortality of many trees of all ages in the site had created a high risk that any fire would completely destroy the old-growth character of the site in an area that had few stands with large-trees and/or large-log structural components. This study site was represented by three stands: two contiguous stands of about 8 ha each that would be harvested in 1994 to reduce fuel-loading, and one untreated control stand of 22 ha. Sampling was done within 10-m-wide belt transects that were divided into contiguous 10-m-long plots. The belt transects were laid out along random azimuths such that they were completely within the study stands. There were 750 m

(75 plots) of belt transect in the treated stands and 400 m (40 plots) of belt transect in the control stand. The same log parameters as for the other studies were collected and summarized on the basis of treatment. Pre-treatment sampling was done in the fall of 1993; salvage logging was done during the ensuing winter of 1993-94 when the forest floor was snow-covered; and post-treatment sampling was done in the summer of 1994. We prescribed harvest activities be conducted only when the ground and logs were snow-covered to minimize log breakage. Previous experience had shown us that the activity of harvesting equipment on bare logs resulted in undue breakage. For this paper, summaries of log resources were combined for the two treated stands, and the control stand was summarized alone. Because this study was completed and published before the Standards were established in 1995, the original data were reanalyzed to produce specific information that would permit meaningful comparisons with the Standards.

Case 4—Selection Harvest/Underburn in Ponderosa Pine

Twelve study stands, approximately 15-75 ha each, were within the La Grande Ranger District, Wallowa-Whitman National Forest, in northeastern Oregon. The stands were equally divided between two areas in the drainages of the upper Grande Ronde River and Spring Creek. Stands were 25-30 km east and south of La Grande. These drainages are dominated by extensive stands of ponderosa pine and mixed conifers. All of the stands had been underburned between 1993 and 1996, and were classified by District silviculturists as being in the understory reinitiation structural stage of Oliver and Larson (1990). The underburn treatment was designed to favor ponderosa pine and western larch by reducing encroachment of Douglas-fir and true firs in the understory. Log sampling was done in 1998. Twenty sampling points spaced at 30-m intervals along randomized transect lines were used to characterize log resources in each of the 12 stands. Each sampling point became the center for three 20-m-long radiating transects along which logs were tallied. Each of the radiating transects was begun 2 m from the plot center. This arrangement yielded 60 m of log-sampling-transect per plot; 1200 m per stand. We tallied each log that was intercepted by a transect.

Results and Discussion

Case 1—Late-structure Stands

Log inventories in the Five-Lock late- and old-structure mixed-conifer and ponderosa pine stands *(table 2)* showed high densities of both large (≥ 30 cm LED) and small (≥15 cm LED) logs, and moderately high densities of large logs as compared with the other cases reported here (cf. *tables 3-5*). These Five-Lock stands have remained largely undisturbed by harvesting for about 40 years. However, in the old-growth sites and the mid- to late-successional mixed conifer sites, quantities of Douglas-fir and grand fir logs were presumably generated as a result of the budworm outbreak of 1980-92. The densities of 59-79 large logs per ha we recorded there are substantially higher than the 37-49 per ha post-harvest densities prescribed in the Standards for mixed conifer stands *(table 1)*. This suggests that well-timed salvage or fuel-reduction harvests might have been prescribed on the grounds of reducing amounts of CWD, and thereby diminish fire risk and hazard. Research by Bull and Holthausen (1993) determined that there were about 240 logs per ha in the pileated woodpecker home ranges that included the very same stands that we inventoried for this case. Using an approximate value of 35 percent large logs (Torgersen and Bull 1995) would yield about 84 large logs per ha within those home ranges. This is close to the range we determined for these stands. The relationship of the densities of 59 and 79 large logs per ha to the 84 logs per ha observed by Torgersen and Bull (1995) is unclear. They may be either functionally lower or may be approaching an acceptable number for use by pileated woodpecker.

Table 2—*Log resources on the Five-Lock Demonstration Area, North Fork John Day Ranger District, Umatilla National Forest, Forest Service, U.S. Department of Agriculture, 1993.*

	Logs ≥ 15 cm in large-end diameter						Logs ≥ 30 cm LED[1]	Logs ≥30 cm SED[2]
Stand Type	**Logs per ha**	**Percentage cover**	**m^3 per ha**	**Metric tons per ha**	**Total lineal length (m) per ha**	**Mean log length (m)**	**Logs per ha**	**Total lineal length (m) per ha**
Old-growth	[3]220 (28.2)	6.2	149	48	2,223	10.1	59	206
Mixed conifers	225 (37.1)	5.4	124	40	1,886	8.4	79	183
Ponderosa pine	115 (10.8)	1.5	38	12	658	5.7	25	47

[1] large-end diameter
[2] small-end diameter
[3] standard error in parentheses

With mean log lengths of 8.4-10.1 m, our sites had about 183-206 m of total lineal length of qualifying logs. Home ranges of pileated woodpeckers studied by Torgersen and Bull (1995) and Bull and others (1997) had total lineal lengths of qualifying logs between 294-362 m per ha. These amounts contrast with the 30-43 m of total lineal length prescribed in the Standards. However, it should be mentioned that the Standards were not designed to specifically provide amounts of CWD that would support pileated woodpeckers. Given the contrasts between the Standards and use of the Five-Lock stands by pileated woodpeckers, as well as those reported in the literature for foraging habitat by pileated woodpeckers, managers need to be informed about the presence and needs of certain wildlife species in stands for which harvest prescriptions are planned. Unfortunately, quantitative information about the log-resource requirements for most species of wildlife is not available.

In the Five-Lock ponderosa pine stands, the density of 25 qualifying large logs per ha was much higher than the 7-15 logs per ha prescribed in the Standards. There had been no major insect or fire disturbances in the ponderosa pine stands that corresponded to the budworm outbreak in mixed conifers that would have accounted for these amounts of CWD. Thus, despite harvesting operations with emphasis on removing large pines 40 years ago, there were, nonetheless, relatively large amounts of qualifying CWD as a consequence of normal recruitment from standing trees and snags. Control of fire undoubtedly played a role in maintaining larger amounts of CWD that might otherwise have burned under pre-settlement fire-return intervals.

Case 2—Salvage/Fuel-reduction Harvests

In the aftermath of the western spruce budworm outbreaks and the subsequent activity of the Douglas-fir beetle (*Dendroctonus pseudotsugae* Hopkins) and fir engraver beetle (*Scolytus ventralis* LeConte) in northeastern Oregon from 1980-1992 (Scott and Schmitt 1996), there were vast acreages of standing dead trees that are continually falling and adding to fuel-loading and risk of fire. Because of an active market for chips, many harvest sales were designed to salvage the standing dead volume to diminish the potential for adding further to fuel-loading, especially in mixed conifer stands. This case study followed two such stands in which Forest Service District managers chose the management option of salvaging standing dead trees and removing smaller down logs that were contributing to fuel loading. Prescriptions for these harvests were written with the intent of maximizing the retention of large snags and large logs for their wildlife values, but to remove smaller snags and logs that represented a present or future risk as fuel for wildfire. *Table 3* and *Figure 1* show how amounts of CWD changed between pre-harvest and post-harvest in the Lane and MacKay harvest units. Post-harvest measures of CWD changed in relevant ways. The numbers of all logs remaining post-harvest was significantly higher in Lane ($n = 20$, $t = -3.22$, $p = 0.004$) and MacKay ($n = 20$, $t = -2.65$, $p = 0.016$). The number of large logs increased, but not significantly so. Conversely, the proportional representation of large logs among those remaining on the ground declined slightly. Percentage cover, volume, and tonnage increased only modestly; varying from 1-14 percent (*table 3, fig. 1*).

Table 3—*Log resources before and after a salvage harvest to reduce fuel-loading in two stands with heavy tree mortality resulting from a 12-year outbreak of western spruce budworm (*Choristonerua occidentalis *Free.), in northeastern Oregon, Wallowa-Whitman and Umatilla National Forests, Forest Service, U.S. Department of Agriculture, 1994, 1996.*

	Logs ≥ 15 cm in large-end diameter						Logs ≥ 30 cm LED[1]	Logs ≥30 cm SED[2]
Stand (year)	Logs per ha	Percentage cover	m^3 per ha	Metric tons per ha	Total lineal length (m) per ha	Mean log length (m)	Logs per ha	Total lineal length (m) per ha
Lane Creek (1994)	[3]205 (82.3)	2.9	73	23	1,385	6.8	59	132
Lane Creek (1996)	350 (140.5)	3.3	75	24	1,451	4.1	67	140
MacKay Creek (1994)	385 (156.4)	5.6	95	30	3,565	9.2	37	132
MacKay Creek (1996)	610 (246.3)	6.0	101	32	3,355	5.4	42	197

[1] large-end diameter
[2] small-end diameter
[3] standard error in parentheses

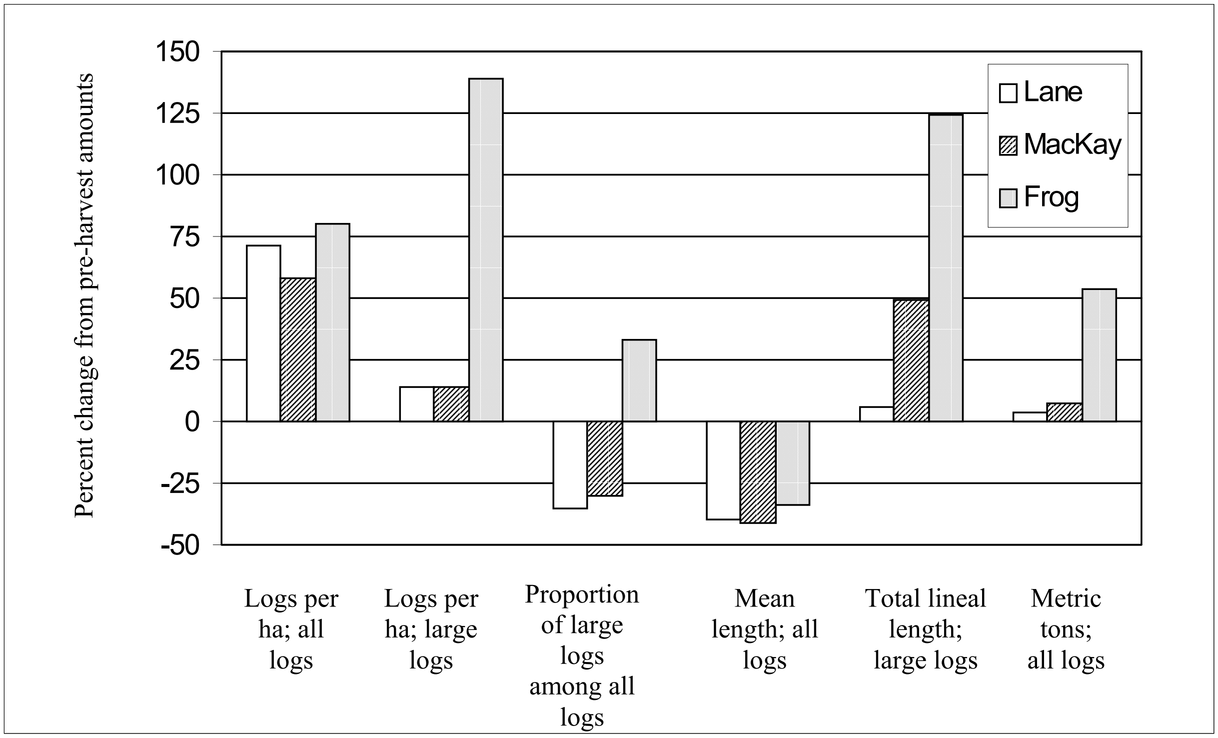

Figure 1—Percentage change between pre- and post-harvest descriptors of log abundance in selected stands treated with fuel-reduction harvests, Umatilla and Wallowa-Whitman National Forests, 1993-1994. “All logs” refers to logs ≥ 15 cm in large-end diameter; “large logs” are those ≥ 30 cm in large-end diameter.

For these two stands, log density alone would have been a poor descriptor of harvest effects on CWD because harvest activity created more but shorter pieces of wood than were present pre-harvest. In the MacKay units, post-harvest log lengths were significantly (n = 20, t = 3.83, p = 0.001) only about half as long as those at pre-harvest (5.4 vs. 9.2 m). In the Lane Creek unit, post-harvest log lengths were about two-thirds as long as pre-harvest log lengths (4.1 vs. 6.8 m), which was only a marginally significant difference (n = 20, t = 2.21, p = 0.041). Taken together, post-harvest log lengths in these units were about 40 percent as long as pre-harvest lengths *(fig. 1)*.

The measures of success of these harvests in terms of their having retained the prescribed desired large log component are mixed. Specifically, the absolute numbers of large logs (≥ 30 cm in LED) per unit area were increased by 14 percent post-harvest, but not statistically significantly so. The percentage composition of large logs among the residual logs was about a third less than at pre-harvest. Percentage composition of large logs among all residual logs fell from 10 percent to 7 percent at MacKay, and from 29 percent to 19 percent at Lane. In something of the same manner as for density of logs, the absolute number of linear meters of these large logs increased by 6 and 49 percent at Lane and MacKay. The proportions of total lineal meters of large logs among all logs remained about constant, at about 5 and 10 percent for MacKay and Lane, for pre- and post-harvest samples, but the changes were not significant in either case. Tonnage of logs was only marginally and nonsignificantly higher post-harvest but was represented mostly in the smaller diameter classes as opposed to the desired larger classes of logs ≥30 cm *(table 3, fig. 1)*. In the overall sense of what sizes and amounts of logs were left at post-harvest, the intent of these salvage harvests did not meet expected goals. However, given that most of the small-diameter standing dead material was salvaged and that the large standing dead trees were retained, then it could be argued that recruitment will come from this desired large-diameter standing dead component.

Case 3—Fuel-reduction Harvest to Retain Old-growth Characteristics

The Frog Heaven site was a designed experiment used to study the potential to reduce fuels in a late-structure stand with many large legacy trees while still maintaining old growth structural components. The unharvested control site showed a large increase in log resources, from 215 to 335 logs per ha, over the course of one season: 1993-1994. This was due to some high wind events that brought down many of the dead trees in the stand. Percent cover in the control sites increased by only 1 percent, but volume and tonnage increased dramatically. Windthrow and breakage were not confined to smaller trees; density of large logs increased twofold, and total lineal length of large logs increased about 40 percent, from 237 to 332 m per ha *(table 4)*.

Table 4—*Log resources after harvest of dead components to reduce fuel-loading and accelerate regeneration in old-growth stands occupied by nesting pileated woodpeckers and Vaux's swifts in northeastern Oregon. Frog Heaven site, La Grande Ranger District, Wallowa-Whitman National Forest, U.S. Department of Agriculture, 1993, 1994.*

	Logs ≥ 15 cm in large-end diameter						Logs ≥ 30 cm LED[1]	Logs ≥30 cm SED[2]
Treatment (year)	**Logs per ha**	**Percentage cover**	**m^3 per ha**	**Metric tons per ha**	**Total lineal length (m) per ha**	**Mean log length (m)**	**Logs per ha**	**Total lineal length (m) per ha**
Pre-salvage (1993)	314	5.6	109	35	3,080	9.5	57	220
Post-salvage (1994)	566	7.4	168	54	3,754	6.3	136	493
Control (1993)	215	4.3	101	32	1,830	8.5	57	237
Control (1994)	335	5.3	165	52	2,160	6.4	106	332

[1] large-end diameter
[2] small-end diameter

In the salvaged stand, the increase in overall log density from 314 to 566 logs between pre- and post-salvage was statistically significant (n = 75, t = -7.33, p = <0.001) and is no doubt attributable, in part, to the same wind events of the intervening winter of 1993-94. Percent cover, volume, and tonnage all increased in much the same way as the control stand. Despite the effort to minimize log-breakage by confining harvesting activity to the period when there was snow cover, mean log length was nonetheless reduced significantly (n = 75, t = 4.36, p = <0.001) in the harvested stands, and as compared with the control stand (33 vs. 25 percent shorter logs), presumably because of the activity of harvesting equipment. The density of large logs in the harvested stands increased statistically, from 57 to 136 logs per ha (n = 75, t = -2.95, p = 0.004), compared to large-log density in the control stand where it increased from 57 to 106 logs per ha *(table 4, fig. 1)*. Some of this increase in the harvested stand might be attributed to the wind events of the winter, and not solely to the logging activity. We observed that many of the larger trees, which were intended to be left standing, were brought down in the process of felling the smaller trees as prescribed. It is interesting how closely the densities of large logs in the late- and old-structure mixed conifer stands of Case 1 *(table 2)* approximate those in the pre-treatment year (1993) at the old-growth stands of Case 3 *(table 4)*.

Because this management case at Frog Heaven was carried out in a research context, there was greater oversight for adherence to the harvest prescription and intent of the harvest. When compared with the Lane Creek and MacKay Creek harvests *(fig. 1),* the Frog Heaven harvest was similar in that it produced more and shorter logs; however, the number, proportional representation, linear length, and tonnage of large logs retained was vastly different. For all these latter variables, the Frog Heaven harvest was significantly higher in the percentage change from the pre-harvest condition (all p-values <0.001 to 0.002). In part, this may have been a function of the greater proportion of large-diameter snags in the stand. It also suggests that if rigid standards of performance are demanded from a logging contractor that preservation of large, legacy logs is possible. One could argue that the greater tonnage of residual logs post-harvest at Frog Heaven constitutes a fuel hazard. However, their overall greater proportional representation and physical size makes them less likely to ignite and burn except in the hottest of fires; thus, for the time being, the intent of reducing fire hazard was met.

Case 4—Selection Harvest/Underburn in Ponderosa Pine

The number of all logs remaining after harvest and underburning in the Spring Creek and Grande Ronde ponderosa pine sites (192 and 72 logs per ha) *(table 5)* bracketed the 115 logs per ha observed in the largely unharvested ponderosa pine stands in the Five-Lock Demonstration area *(table 2)*. Thus, in terms of the overall CWD component, (i.e., excluding the overstory that would provide recruitment for logs in the future), the Spring Creek and Grande Ronde harvest/underburn treatments approximated the relatively undisturbed, (i.e., not recently harvested), ponderosa pine stands in Case 1. The post-harvest/underburned Spring Creek and Grande Ronde stands easily exceeded the Standards for density of large, qualifying logs (20 and 25 logs vs. the Standard of 7-15 logs per ha) and for total lineal length (85 and 130 m vs. the Standard of 6-12 m per ha) *(tables 1, 5)*. As a consequence of the greater mean length of logs in these harvested/underburned sites, total lineal length of logs was substantially greater (85 and 130 m per ha) than in the Five-Lock ponderosa stands (47 m per ha) (*tables 2* and *5*, respectively). This suggests that even after the imposition of selective harvest and underburning in the Spring Creek and Grande Ronde stands, post-treatment density of logs still exceeded those observed in the relatively unexploited Five-Lock Case, as stipulated in the Standards.

Table 5—*Log resources after selection harvest and underburning to favor ponderosa pine and western larch, and reduce encroachment by Douglas-fir and grand fir in northeastern Oregon. La Grande Ranger District, Wallowa-Whitman National Forest, Forest Service, U.S. Department of Agriculture, 1998.*

	Logs ≥ 15 cm in large-end diameter						Logs ≥ 30 cm LED[1]	Logs ≥30 cm SED[2]
Stand (year)	**Logs per ha**	**Percentage cover**	**m^3 per ha**	**Metric tons per ha**	**Total lineal length (m) per ha**	**Mean log length (m)**	**Logs per ha**	**Total lineal length (m) per ha**
Spring Creek (1998)	192	2.7	126	16	184	10.4	20	85
Grande Ronde (1998)	72	0.8	52	6	57	8.5	25	130

[1] large-end diameter
[2] small-end diameter

This Case contrasts with Cases 2 and 3 that resulted in shorter log lengths as a consequence of harvesting activity in mixed conifer stands. Specifically, pre-treatment vs. post-treatment lengths of logs in these ponderosa pine stands seemed to be less affected by harvesting than in those mixed conifer stands (*table 5* vs. *tables 3* and *4*). Presumably, the lower density of logs on the ground allowed harvesting equipment more options of going around rather than over logs, preventing breakage of residual logs.

Conclusions

Overall, it is difficult to assess the success of the salvage/fuel-reduction harvests. Post-harvest tonnage of CWD increased modestly, but presumably the remaining large standing dead trees, which were maintained for their value to wildlife structure, would ultimately contribute less to fuel-loading and hazard on the site than if the small standing-dead component (≤38 cm dbh) had been left to fall. The outcome of these salvage/fuel reduction harvests suggests that fuels were not reduced as much as one might intuitively think. However, the reduction in standing dead volume would represent a lesser fuel risk, and the crushing and breaking down of much of the CWD on the site would lead to fuels being in closer contact with the ground. The crushed fuels would be expected to remain moist longer into the fire season, and to decay more rapidly, minimizing fire risk and hazard for the near future.

A question that remains, however, is whether the residual stands in these four cases will continue to provide the targeted levels of log resources through recruitment of some of the residual trees that die and/or fall. The Decision Notice states that, “it is not the intention of this direction to leave standing trees for future logs in addition to the required snag numbers” (p. 11, Lowe 1995). Thus, it is possible for the Decision Notice Standards for logs to be met after harvest, but not have an adequate cohort of residual trees left to provide for future log resources. The concept of having a sustainable flow of resources, including CWD, is crucial to management, and should be addressed in future standards.

Determining if standards are being met after management prescriptions have been applied, or to otherwise quantify CWD, requires statistically valid and efficient sampling methods for this stratum. Bate and others (2002) present an alternative to the time-honored line-intercept inventory method of Brown (1974) for log sampling. Specifically, their alternative uses a time-saving strip-plot method for measuring density, percentage cover, total lineal length, weight, and volume of logs in stands and landscapes in interior northwest mixed-conifer stands. The method is also adapted to sampling in the lower log densities common in ponderosa pine stands.

Few inventories of log resources routinely use density as an expression of measurement (Bull and others 1995, 1997; Torgersen and Bull 1995), despite the fact that desired densities are stipulated in the Decision Notice Standards. Studies in wildlife ecology commonly use percentage cover to express log resources (Buchanan and others 1999, Carey and Johnson 1995, Carey and others 1999, Wilson and Carey 2000). This variable is also referred to as projected area or projected cover (Caza 1993, Harmon and Cromak 1987, Marshall and others 2000). Thus, for future standards that describe CWD, use of percentage cover (i.e. projected cover) would be a valuable descriptive parameter to include. Overall, for future inventories of CWD, sampling designs should supply information on density, percentage cover, and volume as minimum descriptive parameters for CWD ≥ 15 cm in large-end diameter. Furthermore, measuring large-end diameters as continuous variables—so that they can be categorized according to any desired diameter classes—is a valuable data set for managers.

The new information from these case studies suggests that the Decision Notice Standards, at least for mixed conifers and ponderosa pine, are attainable. But fundamental questions that still beg answers are “How much CWD is enough?” and “Are the Standards sufficiently high or too low?” Some newer published data partly address these questions. Based on the work of Bull and Holthausen (1993) and Torgersen and Bull (1995), for pileated woodpeckers at least, the Standards now appear too low! These data suggest that in pileated woodpecker home ranges the Standards are little more than half of what they could be in terms of pieces per unit area (59 to 77 per ha vs. 37 to 49 in the Standard). The piece-length Standard (> 2 m, with small-end diameter of 30 cm), regardless of management intent is only a third of what now seems appropriate. The concept in the Standards which stated that “longer logs may count for multiple ‘pieces’ without cutting them” (p. 11, Lowe 1995) recognized the value of long logs, but fell short of prescribing appropriately longer logs in sufficient numbers, largely because of the absence of appropriate data at the time. A mean piece-length standard of 6-9 m, for logs with a large-end diameter of ≥ 38 cm, is closer to observed log lengths in mixed conifer stands in northeastern Oregon, for example (Bate and others 2002, Bull and others 1997). Also, the large-end diameter is a more efficient parameter to estimate than the Standards’ small end diameter of 30 cm somewhere along a log’s length. New piece-length standards of 6-9 m would yield a new total lineal length standard approximating 300 to 600 m vs. the 30-43 m of the existing Standard.

The task of prescribing standards for how many, how big, and what kinds of logs to retain after management prescriptions is complex. It cannot be done without consideration for what there is in the residual standing living and dead components from which future CWD will be recruited over time. Having empirical data on CWD to incorporate into predictive models—and then using those models to formulate realistic, attainable standards—is crucial to sustainable forestry. As science and society become more knowledgeable about the complexities of ecosystems and their management, the collection and analysis of empirical data on CWD will be as important as it has been for living trees. Such inventories also need to be coordinated with the habitat needs for selected wildlife species of concern. This will mean support, both within the National Forest System and in research, for aggressive inventory programs that will provide data on CWD that measure up to the same statistical standards as for commodity resources.

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