Compliance with Leave Tree and Downed Wood Forest Practices Act Regulations:

Results from Pilot Study

Oregon Department of Forestry
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ABSTRACT

The Oregon Forest Practices Act (FPA) requires that wood in the form of standing live or dead trees and downed logs be retained during some forest harvest operations for the purpose of contributing to overall maintenance of wildlife, nutrient cycling, moisture retention and other resource benefits of retained wood (ORS 527.676). However, little information is available to confirm whether regulatory requirements are being met. In 2002, we began a pilot study to assist in development of a study design, field methods, and analytical methods that could be used to evaluate rates of compliance with the Forest Practices Act leave tree and downed wood regulations specified in ORS 527.676. Notifications were obtained for 31 harvest operations submitted in 2000 for operations in the Coast Range of Oregon. Notifications and written plans (if available) were reviewed for all 31 operations and field data collection methods tested on five of those operations. Field data included a 100% cruise of leave trees and line intercept surveys for downed logs. Results from field data collection indicated that the 100% cruise for leave trees was effective, but time consuming. In contrast, the line intercept surveys for downed logs were quick and efficient, but not effective enough to determine compliance due to high error rates associated with estimates of log density. Based on our results and on information obtained during consultation with a statistician, we recommend that a strategy that tallies leave trees and downed logs to determine compliance be considered. In addition, at least 70 operations should be sampled for the Coast Range in order to determine compliance rates with adequate precision.

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ACRONYMS

BA—Basal Area
DBH—Diameter at breast height
D—Non-fishbearing streams that are used for domestic water use streams. Refers to streams of any size (large, medium, small)
FIA—Forest Inventory and Analysis
LF—Large fishbearing stream
LN—Large non-fishbearing stream
MF—Medium fishbearing stream
MN—Medium non-fishbearing stream
OAR—Oregon Administrative Rule
ODF—Oregon Department of Forestry
OPSW—Oregon Plan for Salmon and Watersheds
ORS—Oregon Revised Statute
RMA—Riparian Management Area
SD--Standard Deviation
SF—Small fishbearing stream
SN—Small non-fishbearing stream

DEFINITION OF TERMS

Alternate Plan—a written plan proposing practices or protection standards different than those specified in the Forest Practices Act.
Downed log—Refers to a dead tree lying on the forest floor; also referred to as downed wood and coarse woody debris in other publications.
Green trees—Refers only to the live tree component of leave trees required to be retained by the Forest Practices Act.
Leave tree—Refers to the combined retention requirement for standing trees to be left at time of harvest. This term refers to both green trees and snags as a whole.
Oregon Plan for Salmon and Watersheds—Oregon's cooperative effort to restore salmon runs, improve water quality, and achieve healthy watersheds and strong communities throughout the state. As a cooperator, ODF recommends voluntary measures to enhance stream condition (ODF 1998a).
Snags—Standing dead trees.
Type II Harvest— "Green" clearcut with scattered retained trees. The number of retained trees falls below the thresholds listed in Table 1 of the main body of the report. Requires retention of leave trees, but reforestation is not required.
Type III Harvest— Clearcut harvest. The number of retained trees falls below the thresholds listed in Table 1 of the main body of the report. Retention of leave trees and reforestation is required.
Upland—The area of a unit beyond the RMA width specified in the Forest Practices Act, given the size and type of stream.
Written Plan—Plan submitted by an operator which describes how the harvest operation will be conducted, including the means to protect resources, if applicable.

BACKGROUND

The Oregon Forest Practices Act (FPA; ODF 2004) requires that wood in the form of standing live or dead trees and downed logs be retained during some forest harvest operations for the purpose of contributing to overall maintenance of wildlife, nutrient cycling, moisture retention and other resource benefits of retained wood (ORS 527.676). However, little information is available to confirm whether regulatory requirements are being met. Therefore, Forest Practices Monitoring initiated efforts to evaluate compliance with and effectiveness of current statutory requirements for leave trees and downed logs.

This report summarizes results from a pilot study conducted during the summer of 2002 and provides recommendations for further study. As a result of these recommendations, additional field sampling was conducted during 2004 and 2005 with a final report scheduled in early 2006.

Importance of Green Trees, Snags, and Downed Logs

The intent of Forest Practices Act regulations for retaining green trees, snags and downed logs is to "build some within-stand structural diversity into future rotations, which may provide habitat for a variety of wildlife species and help maintain site productivity" (ODF, Forest Practices Rule Guidance as stated for ORS 527.676, hereafter referred to as ORS 527.676 Guidance). A wide variety of wildlife are dependent on trees, snags and downed logs for survival and reproduction. In the Pacific Northwest, 69 vertebrate species use cavities in dead or live trees and 47 species respond positively to amounts of downed wood (Bunnell et al. 2002). Snags are especially important for cavity-using species of wildlife including cavity-nesting birds, flying squirrels, and most species of bats (Bunnell et al. 2002, Hayes 2003). Almost 80% of nests of weak excavators (those that require well-decayed wood to excavate nests) are found in dead trees (Bunnell et al. 2002). Live trees retained during harvest provide immediate and future structural diversity in the harvest unit. Species richness and abundance of some species has been documented to be greater in young stands with "legacy" structures (live trees, snags, and downed logs) from previous stands than in young stands with few to no legacy structures (Zarnowitz and Manuwal 1985, Hansen et al. 1995, Chambers et al. 1999). Live trees that are "wolfy," hollow, partially dead, or have defects such as broken or forked tops or mistletoe infections have been documented to provide important breeding and resting habitat for species of wildlife such as Vaux's swift, marbled murrelets, black bears, and some species of carnivores (Bull et al. 1997, Bunnell et al 2002).

Live trees and dead wood are also critical components of long-term productivity of both forest and stream ecosystems and play an important role in ecosystem processes. Dead wood in forests influences basic ecosystem processes such as soil productivity and development, nutrient immobilization and mineralization, and nitrogen fixation (Rose et al. 2001). Dead wood is well documented as a major source of humus and soil organic matter, which acts to improve soil development. Up to 68% of forest soil is derived from decaying wood and loss of soil organic matter has been demonstrated to be closely linked to loss in soil productivity (Rose et al. 2001). Litter fall from live trees provides a substantial short-term, but continual source of nutrients to forest soils whereas dead wood acts as a long-term source of nutrients (dead wood absorbs nutrients in the short-term but stores nutrients and releases them over time as decay processes progress (Rose et al. 2001). Dead wood typically contains <1 to 4% of the nitrogen and 4 to 11% of the phosphorus in westside forests (Rose et al. 2001). Dead wood has also been noted as

an important component in carbon storage (Harmon 2001). Downed logs also store water, act as nurse-logs for shrubs and regenerating seedlings, and act to reduce soil erosion (Rose et al. 2001).

Dead wood, especially large downed logs are an essential component in stream ecosystems (Naiman et al. 2002). Large downed wood in stream ecosystems plays critical roles in sediment retention, pool formation, and particulate organic matter (e.g., leaves, twigs, needles) storage, which in turn influences nutrient transport and productivity of both invertebrates and fish (Naiman et al. 2002).

Forest Practices Act Regulations (ORS 527.676)

The Oregon Department of Forestry administers Forest Practices Act provisions that require retaining standing trees (hereafter referred to as leave trees) and downed logs for wildlife in some clearcuts (type II and type III harvest units). Wildlife tree and downed log retention regulations become applicable if units are over 25 acres in size and less than a specified density or basal area of trees are left after harvest (Table 1).

Table 1: Thresholds in basal area and number of trees per acre below which leave trees and downed logs are required to be retained.

Site Index	Basal Area (square feet per acre)	Tree Density (number per acre)
I, II, III	33	50
IV & V	20	30
VI	10	15

If leave tree and downed log regulations are triggered, ORS 527.676 requires retention of two snags or green trees and two downed logs per acre, on average, within the unit. Snags and green trees must be at least 30 feet tall and at least 11 inches DBH and each downed log must be at least 6 feet long and contain a total volume of at least 10 cubic feet. At least half the green trees and snags and half of the downed logs left on the unit must be conifers. In most cases (except see Oregon Plan for Salmon and Watersheds provisions below), the operator has full discretion as to which trees, snags, and logs to retain, however they must meet minimum size requirements, be left within the unit, and enough must be left to account for the two per acre requirement (i.e., a total of 50 leave trees and downed logs must be left within a 25 acre unit, but they can occur anywhere within the unit boundary).

Compliance with leave tree and downed wood retention requirements do not require a written plan. However, if a written plan is required due to other statutory or administrative rules, the location of leave trees should be indicated on the map submitted with the written plan (ODF, Forest Practices Rule Guidance as stated for OAR 629-605-170). Location of downed wood does not need to be included on the map submitted with the written plans.

Alternate plans are allowed to meet the provisions of ORS 527.676, including waivers for the following:

1) Waiver of the 50% coniferous requirement for sites being intensively managed for hardwood production.

2) Retention of leave trees may be waived if equal or greater number of trees retained in another operation would achieve better overall benefits to wildlife.

Oregon Plan for Salmon and Watersheds Recommendations

The Oregon Plan for Salmon and Watersheds (ODF 1998a) recommends that leave trees be left in riparian areas to provide added benefit to fish. In support of the Oregon Plan for Salmon and Watersheds, ODF may require that up to 25% of leave trees be retained near fishbearing or domestic use streams within the unit (ORS 527.676.3.c). The Oregon Plan for Salmon and Watersheds also has voluntary measures that recommends that leave trees be voluntarily located along streams (Type N, D, or F) and that the conifer component be increased from 50% to 75% (ODF 1998a).

ODF Guidance

ODF has published guidance regarding leave tree and downed wood retention regulations (OAR 527.676 Guidance; ODF 1998b). The guidance reiterates the size requirements of trees, snags, and logs to be retained. In addition, the guidance indicates that heavily decayed logs (decay class IV and V) cannot count towards the downed log requirement. At some point in time, downed logs decay enough that they become soil; it is assumed that downed logs in decay classes IV and V function as soil and not as logs. Decay class IV and V logs are described as those in which bark is absent, twigs are absent, log shape is oval, wood texture consists of small, soft, blocky pieces, wood color is light brown to reddish brown; and invading roots are present in the heartwood. A general guideline is provided that if the log would break apart if pulled by a choker, it should not be counted towards the downed log requirements. The guidance notes that all leave trees that meet the minimum dbh and height criteria can count towards the leave tree requirements (implying that snags of all decay classes can count). It also notes that retained leave trees and downed logs are to be retained until "they are replaced in the unit over time".

In general, trees and snags required to be left for protection of other resources (e.g., wetlands, specified resource sites), cannot be counted towards leave tree requirements. However, green trees occurring within some riparian management areas (RMA's) can double-count towards leave tree requirements (ODF 1998c, Table 2; also see Appendix I).

The leave tree and downed wood guidance document also provides information on the types of trees and logs that are likely to provide the greatest value to wildlife. This guidance is not subject to enforcement action. It includes the following recommendations for leave tree retention strategies:

- Large, unsound trees are preferred over smaller, sound trees.
- Retention of the largest trees in the stand is suggested.
- Retention of a combination of live and dead trees is preferred.
- Douglas-fir and Western redcedar are recommended over other tree species in western Oregon and Ponderosa pine is recommended in eastern Oregon. Red alder is noted as the least preferred species for retention.

- Retention of wind-firm trees or trees located in sheltered areas of the unit.
- Retention of leave trees along type N streams.

Table 2: Live trees and snags in RMA's that count towards leave tree targets[1].

	LF and MF[3]	SF, LN, MN, and all type D streams[3]	SN streams[3]
Live trees[2]	Conifers beyond those needed to meet the active management target All hardwoods > 20 ft from the stream	All trees	All trees
Snags[2]	None	None	All snags

[1]Adapted from Page 5-20, Forest Practices Field Guide (ODF 1998c); also see Appendix I.
[2]Trees and snags must be ≥ 11" dbh and ≥ 30 ft tall to qualify as leave trees
[3]Stream Classes: LF=large fishbearing, MF=medium fishbearing, SF=small fishbearing, LN=large non-fishbearing, MN=medium non-fishbearing, SN=small non-fishbearing, D = domestic water use streams

Monitoring Need

Compliance monitoring for leave tree and downed wood regulations was identified as a top priority in the Forest Practices Monitoring Strategic Plan (ODF 2002a). In particular, the strategic plan identified the following questions:

- Question 32—"What are compliance rates with retention of leave trees and downed logs?
- Question 39—"Do the leave trees and downed log requirements provide for wildlife habitats as intended?
- Question 40—"What are the implications of preferentially retaining leave trees along streams in support of the Oregon Salmon Plan?"

OBJECTIVES

The primary objective of this pilot study was to develop a study design, field methods, and analytical methods that would best address Question 32 (compliance rates). To the extent practicable, the intent was to develop a study design that would also allow for the gathering of information to address the remaining questions. Specifically, we wish to collect data to describe the condition (e.g., species, size, decay class) of trees and logs retained, which could then be used to address the ability of the requirements to provide wildlife habitat (Question 39). In addition, we hope to evaluate the proportion of leave trees retained along streams. This information may inform Question 40.

METHODS

Three types of data were collected: 1) information compiled from notification, written plans, and through consultation with Forest Practices Foresters and landowners, 2) data from a 100% cruise of all standing live and dead trees in the unit, and 3) data collected on downed logs from line-intercept transect surveys.

Site Selection

The pilot study focused on harvest units in western Oregon, specifically in ODF West Oregon, Forest Grove, and Clackamas-Marion Districts[1]. A random sample of 31 non-federal harvest units was identified using the Department's Forest Activity Computerized Tracking System (FACTS) database and through consultation with ODF Forest Practices Foresters. Timber harvest units were selected that had a notification submitted in 2000 for a planned clearcut (Type II or Type III) harvest at least 25 acres in size, and for which harvest was planned to be completed by summer 2002. Of the 31 units, field visits were conducted on five units. These five units were selected based on logistical preference and time constraints.

General Timber Harvest Unit Data

In order to determine the extent that locations of leave trees and downed logs could be determined prior to field work, notifications and written plans (if applicable) were obtained and the Forest Practices Forester and landowner were consulted to gather available information on the locations of leave trees in the harvest unit.

In addition, the following data was recorded to provide a general description of the unit:

- Landowner type (private industrial, private non-industrial, other)
- Notification number
- Forest Practices Forester name
- Unit size (acres)
- Legal description (Township, Range, Section)
- Leave tree and down log locations described in written plan or submitted map

[1] Through a consolidation of district boundaries, the Clackamas-Marion district is now part of ODF's North Cascade District.

Leave Tree Surveys
At each selected harvest unit, surveyors documented pattern of dispersion of leave trees (scattered, grouped, along unit boundary, within RMA [size/type and length], on a high risk slope, other). A 100% cruise of leave trees was conducted on 4 of the 5 units. For one unit, trees contained within a medium fishbearing stream were not sampled due to time constraints. This section of stream may or may not have contained leave trees as only trees retained beyond the active management target would have counted towards leave tree requirements.

Standing leave trees ≥ 11" DBH in the harvest unit had the following data recorded:
- Diameter at breast height (inches)
- Species
- Decay class (using U.S. Forest Service three-class decay rating system, Bull et al. 1997)
- Estimated distance from channel if tree is in a riparian management area (RMA)
- Estimated tree height (feet)
- Windthrow since harvest (yes/no)

In order to be able to separate trees retained to meet RMA basal area requirements from those retained to meet leave tree requirements, all trees ≥ 6" dbh were also measured in RMA's. Furthermore, the protocol described in Appendix I was created to determine which trees within RMA's of large and medium fishbearing streams would be in excess of RMA targets, and thus count towards leave tree requirements. Because no large or medium fishbearing streams were surveyed, this protocol was not tested during this study.

Downed Log Surveys
Pattern of down log dispersion (scattered, grouped, along unit boundary, in RMA) was noted based on visual inspection of the unit. At each selected harvest unit, detailed data was collected on down logs surveyed along two 1000-foot line-intercept transect surveys. Transect locations were identified prior to the field visit using the following randomly selected variables: starting edge of unit (N, NE, E, SE, S, SW, W, NW), distance from the unit edge to start of transect, and azimuth for direction of transect. Because downed logs within RMAs cannot be counted towards retention targets, all transects were located outside of RMAs. The following data was collected for each log (> 6" diameter at the small end and > 6' long) intercepted by the transect:
- Species
- Log diameter at small end (inches)
- Log diameter at large end (inches)
- Estimated average log diameter (inches)
- Length of log (feet)
- Decay class (using U.S. Forest Service three-class decay rating system, Bull et al. 1997)

To evaluate whether a downed log was large enough to meet Forest Practices Act requirements, we calculated volume for each downed log measured. Downed logs qualified towards Forest Practices Act requirements if they were at least 6 feet long and contained at least 10 ft^3 of volume. We used the equation for volume of a frustum of a paraboloid to calculate volume of downed logs (Harmon and Sexton 1996).

$$V = L\,(A_b + A_t)/2$$

Where V is volume (ft^3), L is length of log (ft), A_b is area at large-end (ft^2), and A_t is area at small end (ft^2).

Once a list of "qualifying logs" was determined for each unit, density (number per acre) of downed logs was calculated. The following expansion equation was used to convert data collected on transects to determine number of qualifying logs per acre (DeVries 1973):

$$\text{Pieces per acre} = \quad (43{,}560 \text{ sq. ft/acre}) * \frac{\pi}{2L} * \sum_{i}^{n} \frac{1}{l_i}$$

L = transect length (feet)
l_i = length (feet), of the *i*th piece of wood
i = denotes *i*th individual piece of wood
n = total number of pieces of wood

This equation is the standard equation used to extrapolate data collected from a line-intercept survey to per-acre estimates and is used as part of the Forest Inventory and Analysis (FIA) sampling protocol (Waddell 2002). Since larger logs are more likely to be intercepted by a transect, the DeVries (1973) extrapolation gives a lower piece per acre weight, the longer the piece length. Waddell (2002) provides an excellent summary of the sampling theory and history behind the DeVries (1973) equation.

RESULTS

Characteristics of Pilot Study Sample

Of the 31 randomly selected units 78% were on industrial and 22% on non-industrial forestlands (Appendix II). Units averaged 61 acres (± 29 sd, range 25-120). Written plans were submitted for 12 units. Streams were present in or adjacent to 26 units (Table 3).

Table 3: Types of streams associated with pilot study units.

Stream Class	Number of Units	Percent of units
Large Fishbearing	4	15%
Medium Fishbearing	5	19%
Small Fishbearing	6	23%
Large Non-fishbearing	0	0
Medium Non-fishbearing	2	8%
Small Non-fishbearing	9	35%
Domestic Waters (any size)	0	0

Characteristics of Measured Harvest Units

Data was collected on five units selected from the pool of randomly selected units based on logistical preferences and time constraints. All were located in the Forest Grove District. Because they were not randomly selected from the pool of possible units, they are not a representative sample and results presented in Tables 4-6 are likely not indicative of the Forest Grove district or the Coast Range georegion. Data is presented to illustrate the condition of the harvest units used to test the field protocol.

Of the five units measured, all were clearcuts on industrial forestlands. Size of units ranged from 31 to 96 acres (Appendix II). Three of the units had written plans associated with them. All five units had streams in or adjacent to them; four had small non-fishbearing streams and one had both medium non-fishbearing and medium fishbearing streams. One unit also contained a small, ½ acre wetland.

Total numbers of leave trees per unit ranged from 81 to 578. A majority of leave trees were located within RMA's (Table 4). Leave trees were voluntarily retained along small non-fishbearing streams in 4 of the units. Density of leave trees ranged from 2 to 16 per acre (Table 5). Estimates of mean density of downed logs ranged from 25 to 67 logs per acre (Table 6).

Table 4: Locations of leave trees and downed logs retained on five units measured in the Forest Grove District.

Unit	Location of Leave Trees		Location of Downed logs
	Riparian Leave trees	Upland Leave trees	
1	94% along SN Stream	6% scattered trees	Scattered throughout unit
2	> 99% along MN stream[1]	Single tree in unit	Scattered throughout unit
3	>99% along SN Stream	< 1% scattered trees in unit	Scattered throughout unit
4	66% along SN stream	34% in small upland wetland	Scattered throughout unit
5	80% along SN stream	20% in a single clump in unit	Scattered throughout unit

[1] A small section of MF stream was not measured in this unit. This section of stream may or may not have contained leave trees as only live trees retained beyond the active management target would have counted towards leave tree requirements.

Table 5: Density (number of trees per acre) of qualifying[1] leave trees retained on five units measured in the Forest Grove District.

Unit	Green Trees	Snags	All Leave trees
1	2.03	0.35	2.38
2[2]	≥ 2.96	0.01	≥ 2.97
3	14.84	0.78	15.62
4	3.23	0.18	3.41
5	4.47	0.16	3.63

[1] Qualifying leave trees are those that meet minimum size requirements.
[2] A small section of MF stream was not measured in this unit. This section of stream may or may not have contained leave trees as only live trees retained beyond the active management target would have counted towards leave tree requirements.

Table 6: Density (number of pieces per acre) of qualifying[1] downed logs retained on five units measured in the Forest Grove District.

Unit	Transects		Unit Estimates[3]	95% Confidence
	A[2]	B[2]	Average (sd)	Interval
1	16.28	34.00	25.14 (12.53)	0 to 138
2	29.59	51.57	40.58 (15.54)	0 to 180
3	56.24	21.55	38.90 (24.53)	0 to 259
4	67.57	34.81	51.19 (23.16)	0 to 259
5	79.86	53.52	66.69 (18.62)	0 to 234

[1] Qualifying logs are those that meet minimum size requirements.
[2] Values derived using DeVries (1973) equation.
[3] Values (# of pieces) derived from estimates from two transects per unit.

FINDINGS AND CONCLUSIONS

Written Plans

Of the 12 written plans and maps reviewed, seven had information regarding distribution of leave trees (Appendix II). Because written plans were usually triggered by the presence of streams, the focus of the written plans addressed how compliance with riparian rules was being met. Thus when mentioned, location of leave trees was typically described as occurring "within the RMA." None of the written plans had information regarding location of downed logs (this is not a requirement of written plans). However, many written plans indicated "leave areas" would be left, suggesting that both leave trees and downed logs might be retained in those leave areas.

Sampling Efficiency

Of the 31 units selected for sampling, field measurements were completed for only five units. This was due mainly to length of time required to measure each unit. Logistically, it took much longer to locate units in the field than expected. Extensive road networks on large private industrial forestlands, inadequate signage, and inaccurate forest road maps contributed to problems locating harvest units in the fields. In addition, it took an excessive amount of time to conduct a 100% inventory of all standing trees for most of the units. The extensive time required to sample units was related to difficulty moving around in the unit and the higher than expected number of trees requiring inventory. Overall, it took 4 hours to 2 days to measure all trees in a single unit. The use of transects rather than full inventory of downed logs undoubtedly saved time. We estimate that it took 2 to 4 hours to sample both transects in a unit. The above estimates of workload do not include travel time to and from the unit.

Sampling Adequacy

Leave Trees

Use of full inventory to sample all standing live and dead trees allowed us to evaluate compliance without any error. A partial sampling scheme would result in an estimate of density of standing trees and snags with an associated "error" rate. Thus, if a unit contained a density of leave trees that was close to 2.0 per acre, there may be some uncertainty as to whether that unit was actually compliant or noncompliant.

We conducted a full inventory of all standing live and dead trees primarily so that leave trees could be separated from those trees left for compliance with riparian rules. Given that standing live trees retained to meet riparian rules can double-count as leave trees for small fishbearing, all domestic water use, and all non-fishbearing streams (Table 2, also see Appendix I), a partial inventory for units with these RMA types would have been adequate. Specifically, trees between six and 10.9 inches would not have to be measured and sampling could cease once enough trees were tallied to confirm that compliance with the regulations had been met. A full inventory of all standing live and dead trees ≥ six inches dbh within large and medium fishbearing streams will likely still be necessary. For large and medium fishbearing RMA's, data will need to be collected in the field and then the protocol in Appendix I used to determine which trees within the RMA can be used to count towards compliance with the leave tree regulations.

Downed Logs

A 100% cruise of all downed logs in each unit was not feasible. Unlike trees and snags, which are conspicuous, shrubs, herbaceous cover, and topographic features easily obscure most downed logs. Nearly the entire unit would have to be traversed to locate all downed logs and to adequately conduct a 100% cruise of downed logs. Thus a partial sampling scheme is the only practical option for downed logs. However, the method used to sample downed wood may not be sufficient for determining compliance with downed wood requirements for each unit. Confidence intervals calculated from our transects were extremely large, ranging from zero to over 130 logs per acre (Table 6). Correspondingly, our certainty with regard to whether there were at least two pieces of downed wood per acre was relatively low. Although the unit mean and the upper end of every confidence interval was much greater than 2.0, the lower end of the confidence interval was calculated to be a highly negative value (but was truncated to 0.0 since negative values were unrealistic [Table 6]). Interpretation of the confidence interval values indicates that the true density of downed logs is equally likely to be any value within the bounds of the confidence interval. Thus, for Unit # 1 we are 95% sure that the true density of downed logs is somewhere between 0.0 and 138.0 pieces per acre, but it is equally likely to be any value between 0.0 and 138.0. There is a 5% chance that the value may exceed 138 pieces per acre.

Part of the reason behind the extremely large confidence intervals that we observed may be due the fact that we sampled only two transects per unit. Confidence intervals bounds were calculated by adding or subtracting the following value from the unit mean: standard error of the mean * t-value (for 0.05 probability and 1 degree of freedom [df]). Thus both the standard error and the t-value can greatly affect the width of a confidence interval. Estimates of dispersion around a mean (including estimates of the standard error) and t-values increase with decreasing sample size (Steel et al. 1997). In our case, the t-value used to calculate confidence interval values was 12.71 (df = 1) where as the t-value for a sample size of three transects (df=2) would have been 4.30.

It may be possible to reduce estimates of sample variance (including standard error) without increasing total length of transect by measuring greater number of smaller length transects (e.g., 10 200 ft or 20 100 ft transects). Marshall et al. (2000) and Pickford and Hazard (1978) have noted that the total length of transect sampled in a unit is more important in reducing sampling variance than is the number or length of individual transects. The 2000 ft sampled per unit is likely adequate as most studies evaluating sampling strategies for downed logs tested shorter lengths and found them to be adequate (Bate et al. 2002, Nemec and Davis 2002). However, Marshall et al. (2000) note that although the total length of transect is important in reducing sampling variance, the robustness to number and length of transects breaks down at the extremes (i.e., few long transects and many very short transects). Thus our use of two 1,000 ft transects might not be adequate to minimize sampling variance; use of four to ten shorter transects may help to reduce sampling variance.

However, regardless of the number of transects sampled, use of the line intercept method will always result in some value for sampling variance. Thus there will always be some uncertainty with regard to the true density of downed logs in a unit. For units with a true density of downed logs close to 2.0 per acre, sampling variance will likely always be problematic even if many

transects are used to sample downed logs because the confidence interval will likely fall below the value of 2.0. This suggests that perhaps a better approach would be a tally of downed logs. This would be similar to a 100% cruise of downed logs except that data collection would cease when compliance was determined to have been met. For units that were non-compliant, the entire unit would still have to be surveyed.

Statistical Consultation

Following data collection from this pilot study, we obtained consultation from a statistician regarding the best sampling design for a full study on evaluation of compliance with leave tree and downed wood regulations. We were advised that because the primary focus of our project was to evaluate rates of compliance, it would be important to avoid sampling error and to determine compliance for each unit with 100% certainty. The statistician suggested that a full tally of the number of trees and logs necessary to achieve compliance would be an adequate approach.

Furthermore, the statistician provided coarse guidelines for number of units needed to be sampled to adequately determine rates of compliance. The number of units to sample is determined by the *a priori* guess of what the true rate of compliance is, the precision that is desired for estimating the true rate of compliance, and the desired level of confidence in the resulting estimate. Calculations for sample size obtained from the statistician were based on the assumption that there were an infinite number of units available for sampling. In reality, the number of units in the population can be determined based on ODF's notification system. A query of the FACTS database for clearcuts > 25 acres in size within the Coast Range and on non-federal and non-state lands indicated that approximately 900 notifications were submitted for such operations each year in 2003 and 2004. Thus, we assumed that the population of possible units available for sampling was 900 for the Coast Range and recalculated the sample size requirements using this correction. Results are presented in Table 7.

Based on conversations with ODF Forest Practices Foresters, we believe actual rates of compliance with Forest Practices Act leave tree and downed wood regulations are likely high. In addition, high rates of compliance (> 96%) with other Forest Practices Act regulations were previously documented (ODF 2002b). Thus, we feel that an estimate of 95% compliance is reasonable. In addition, we accepted a precision of 5% as adequate. Consequently, if we assume that the true rate of compliance is 95% and we wish to estimate rate of compliance to within 5% of the true rate, we would need to sample 68 units. If we wish to be within 2% of the true rate, the sample size required would jump to 303 (Table 7).

Table 7: Sample size requirements to determine rate of compliance given an *a priori* guess of what the true rate of compliance is and the precision that is desired for estimating the true rate of compliance.

Assumed True Rate of Compliance	Desired Precision	Sample Size Required	
		Based on an infinite population [2]	Based on a finite population of 900 [3]
0.95	0.01	1824	603
0.95	0.02	456	303
0.95	0.05	73	68
0.95	0.10	18	18
0.90	0.01	3457	715
0.90	0.02	865	442
0.90	0.05	139	120
0.90	0.10	35	34
0.80	0.01	6146	786
0.80	0.02	1536	568
0.80	0.05	245	194
0.80	0.10	61	58

[1] All calculations are based on a 95% confidence interval (alpha value of 0.05)
[2] Sample size values from an infinite population were provided to us by a statistician.
[3] Sample size values from a finite population were calculated by ODF staff using a online calculator located at www.raosoft.com/samplesize.html and based on a finite population of 900.

Recommendations for future sampling

Based on our observations during this pilot study and on advice from the statistician, we developed the following recommendations.

1) A full-scale study determining rates of compliance with regard to leave tree and downed wood regulations for a particular region can also address the following secondary objectives.

   - Provide information on the size, density, distribution, and characteristics of leave trees retained.

   - Provide information on the size, density, distribution, and characteristics of downed logs retained.

   - For units with streams in or adjacent to them, evaluate what proportion of leave trees are retained in the stream riparian management area, in accordance with recommendations of the Oregon Plan for Salmon and Watersheds.

2) We propose that a strategy that tallies leave trees and downed logs to determine compliance should be explored. Methods using plots or line transects for sampling should be avoided.

3) Continue to obtain written plans prior to field visits to help field crews become familiar with units prior to field measurements. In addition, written plans contain information on the types of streams in or adjacent to the unit, the length of those streams, as well as information on other resources being protected (i.e., wetlands). This information can be used to estimate workload needed to sample units prior to conducting field visits.

4) Conduct preliminary field "tours" with Forest Practices Foresters or landowners to help reduce the amount of time required to locate units in the field.

5) Draw maps indicating locations of leave trees. In addition, consider mapping leave trees using a GPS to allow for the option for future resampling to determine the "life-span" of leave trees and snags.

6) For sampling within the Coast Range, attempts should be made to sample at least 70 units. For other georegions, new FACTS queries should be conducted to determine the population of units available for sampling sample sizes recalculated. Sample size calculations should be specific to each georegion.

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Appendix I: Protocol for addressing Forest Practices Act leave tree compliance for units with riparian management areas.

When harvesting near a fishbearing stream, a minimum basal area (BA) of trees must be left in order to meet riparian management area (RMA) requirements specified in the Forest Practices Act (OAR 629.640.100 through OAR 629.640.200). Landowners/operators have the option to locate leave trees within the RMA in order to provide added benefit to the stream (OAR 629.640.0100.11, OAR 629.640.0200.6.b). Leaving some or all of the leave trees in the RMA is recommended in the Oregon Plan for Salmon and Watersheds. In some cases Forest Practices Foresters may require that 25% of the leave trees be left within the RMA (ORS 527.676.3.c).

In most cases all live trees ≥ 11" dbh and ≥ 30' tall left within the RMA can also count towards leave tree requirements (see Table 2 in the main body of the report). This is true for all non-fishbearing streams, all domestic water streams, and for small fishbearing streams (OAR 629.640.0200.12, OAR 629.640.0100.11.b). In medium and large fishbearing streams, live trees retained in addition to those needed to meet the active management basal area target can also count towards leave tree requirements (OAR 629.640.0100.11.a). Except for a few exceptions, snags within the RMA cannot count towards leave tree requirements (OAR 629.640.0100.6, OAR 629.640.0100.7.b, OAR 629.640.0200.8.b).

For units with medium or large fishbearing RMA's, a methodology was needed to determine which trees were left to meet RMA basal area retention requirements versus which trees were left to meet leave tree requirements. This step is critical for determining compliance with the leave tree requirements in situations where most or all of the leave trees are left within or adjacent to the RMA.

The step by step approach below applies ONLY for medium and large fishbearing streams. It is designed to be used for units in which a full inventory of all standing live and dead trees is conducted within the RMA. The intended purpose of the approach is to determine which trees from the full tree list qualify as leave trees. Throughout the approach, each tree in the list will receive a label (Y or N) for both a RMA and a leave tree (LT) field that will indicate whether that individual tree is used to meet either RMA and leave tree targets. The final list of trees with a "Y" in the LT field will represent those trees that count towards the leave tree requirements. This list of trees can then be used to determine compliance and to describe characteristics of leave trees retained within the riparian management area.

The approach below is meant to be used as a step-by-step approach. During each step, labels are added to trees in the tree list. Labels assigned in early steps should be retained throughout the process and new labels added only to previously unlabeled trees. For example, a label of "N" is assigned for the leave tree field for all trees that are < 11" dbh in step 3. In step 4a, only alders 11-24" dbh should be labeled as "Y" for leave trees; the label of "N" for trees < 11" dbh should not be changed.

To determine a list of qualifying wildlife trees, the following strategies were used

1) RMA targets were made up FIRST by trees and snags that could be applied towards RMA targets but that could not qualify as wildlife trees because they were too small or too short.
2) Trees within the 0-20' zone were used to count towards RMA targets because these trees were not available for harvest.
3) If available, Cottonwoods and Ash were used before conifers to meet RMA targets.
4) Red alders were counted towards leave tree requirements because they cannot be used to meet RMA targets.
5) The largest conifers were used first to meet RMA targets. This strategy gives the benefit towards the landowner because a larger number of trees will qualify as leave trees.

Step by Step Approach for determining which snags and live trees in a RMA count towards leave tree targets for the Coast Range, South Coast, Interior, Western Cascade, and Siskiyou Geographic Regions.

For Medium and Large Fishbearing Streams ONLY. For streams with two-sided RMA's, each side must be evaluated separately.

Step	Description of Step	Value*
	First Step: Determine riparian management area (RMA) basal area (BA) values for later use.	
1a	Determine the active management basal area target value (BA per 1000 ft of stream) applicable given the appropriate stream classification (see OAR 629.640.0100.6.a). USE ACTIVE MANAGEMENT TARGET value, even if the RMA was subject to the standard target.	
1b	Determine the total length of medium and large fishbearing stream in and adjacent to the unit	
1c	Adjust the required BA level by the length of stream to determine the TOTAL minimum BA needed before leave trees can be counted.	**Aa**
1d	Determine the standard basal area target value. The standard target is calculated in the same manner as the active management target (steps 1a to 1c) except that the standard target value is used in step 1a.	
1e	Multiply the standard target BA retention value obtained in step 1d by 0.10. The Ab value will be used later to determine which snags and hardwoods can be counted towards riparian basal area retention targets.	**Ab**
2	**Second Step: Develop a tree list for the RMA and label each tree for species classes based on criteria in Table I-1. If not already present, calculate the basal area for each tree.**	

* Assigned value for later use in subsequent steps.

	Third Step: Label trees the set of trees whose categories can be readily determined without evaluating basal area.	
3a	If inventoried, all live trees and snags that are < 6" dbh. *Label as N for leave tree and N for RMA tree.*	
3b	All live trees and snags 6.0 – 10.9" dbh. *Label as N for leave tree*	
3c	All live trees and snags < 30' tall. *Label as N for leave tree*	
3d	Hardwood snags (HWS) within the RMA. *Label as N for leave tree and N for RMA tree*	
3e	Conifer snags (SCS or NQCS) within the RMA *Label as N for leave tree*	
3f	All trees & snags that fall outside the standard RMA width. *Label as Y for leave tree and N for RMA tree*	
3g	If species = ALD. *Label as Y for leave tree and N for RMA tree*	
3h	If species = OH or CW/ASH AND distance from creek ≤ 20. *Label as N for leave tree and N for RMA tree*	
3i	If species = OH AND dbh < 24" AND distance from stream > 20'. *Label as Y for leave tree and N for RMA tree*	
	The remaining trees should represent those that could potentially count towards either RMA or WLT targets	
	Fourth Step: Figure out which SCS and OH to count towards the 10% allowance towards RMA BA retention requirements *Reasoning: Up to 10% of the Standard RMA BA retention target may be made up by snags and qualifying "other hardwoods".*	
4a	Add up the BA for all SCS within the RMA.	Ba
4b	Add up the BA for all OH that are ≥ 24" dbh and > 20 ft from creek	Bb
	Add Ba and Bb	Bc
4b	If Bc ≤ Ab (i.e., comprises ≤ 10% of total RMA BA retention target), then use all snags and qualifying hardwoods towards RMA BA retention requirement. *Bd = Bc.* *Label all SCS and OH as Y for RMA tree.*	**Bd**
4c	If Bc comprises > 10% of total RMA BA retention target, then Bd = Ab. Determine which combination of SCS and OH trees whose total BA most closely meets the Bd value and *label as Y for RMA trees. Label any remaining OH or SCS trees as N for RMA tree.*	**Bd**

	Fifth Step: Meet as much of the riparian BA retention target as possible with trees that cannot qualify as leave trees and cottonwood/ash trees (can double-count as leave trees)	
5a	Add up the BA for all live trees between 6 and 11 " dbh and all live trees < 30 ' tall *Reasoning: too small or too short to qualify as WLT* *Label as N for leave tree and Y for RMA tree*	**C**
5b	If stream class = LF, add the BA for all CW/ASH. *Label as Y for leave tree and Y for RMA tree (can double-count)*	**D**
	Sixth Step: Figure out whether RMA BA requirements are met	
	Add Bd + C + D	**X**
6	Subtract X from A	**Y**
	If Y is zero or a negative value, then the BA requirements has been met or surpassed. All remaining trees in the cruise list will qualify as RMA WLT. *Label all remaining trees as Y for leave tree and N for RMA tree*	
	If Y is positive, then Y represents the remaining BA that needs to be accounted to meet the minimum BA requirements for the RMA. The remaining trees in the cruise list represent the "pool" of trees that could be available either as RMA trees or as RMA leave trees.	
	Seventh Step: Figure out which remaining trees will be used as RMA BA trees	
7	Sort the remaining list of trees in descending order by BA. Add the BA of the trees, using the largest trees first until the cumulative BA ≥ Y. *Label as N for leave tree and Y for RMA tree*	
	Ninth Step: Compile final list of trees that qualify as leave trees	
9	All remaining trees in the list qualify as leave trees *Label as Y for leave tree*	
	Double-check labels for all OH, ALD, and CW/ASH that are > 20' from the stream. Labels should be Y for leave.	
10	*Report the final calculations for RMA BA. Confirm that RMA BA≥Aa*	
	Report the final number of leave trees; sum conifers and hardwoods separately	

Table I.1. Criteria used to assigned species classes for trees within large and medium fishbearing RMA's.

Stream Class	Live/Dead	Decay Class	Height	Tree Species	Code*
MF or LF	Live	n/a	n/a	Any conifer species	CONI
MF or LF	Dead	1 or 2	≥ 30' tall	Any conifer species	SCS
MF or LF	Dead	1 or 2	≤ 30' tall	Any conifer species	NQCS
MF or LF	Dead	3	n/a	Any conifer species	NQCS
MF or LF	Live	n/a	n/a	Red Alder	ALD
LF	Live	n/a	n/a	Oregon White Ash	CW/ASH
LF	Live	n/a	n/a	Cottonwood (any species of cottonwood)	CW/ASH
MF	Live	n/a	n/a	Any hardwood tree besides red alder	OH
LF	Live	n/a	n/a	Any hardwood tree besides red alder, cottonwood, or ash	OH
MF or LF	Dead	Any	n/a	Any hardwood Species	HWS

* ALD = red alder, ASH = Oregon white ash, CONI = conifer tree, CW = cottonwood, HWS = hardwood snag, NQCS = non-qualifying conifer snag, SCS = sound conifer snag.

Appendix II: Summary of randomly selected units initially selected for the pilot study. Units in bold are those where field protocols were tested.

District	Owner Type	Unit Size (ac)	Harvest Type	Written Plan?	Stream (type)	Other protected resources with leave trees
Forest Grove	**Industrial**	**34**	**Clearcut**	**Yes**	**SN**	
Forest Grove	**Industrial**	**75**	**Clearcut**	**Yes**	**MN, MF[1]**	
Forest Grove	**Industrial**	**37**	**Clearcut**	**No**	**SN**	**0.5 ac wetland**
Forest Grove	**Industrial**	**71**	**Clearcut**	**No**	**SN**	
Forest Grove	**Industrial**	**96**	**Clearcut**	**Yes**	**SN**	
Forest Grove	Industrial	52	Clearcut	Yes	SN	
Forest Grove	Industrial	80	Clearcut	No	none	
Forest Grove	Industrial	105	Clearcut	Yes	LF, MF	
Forest Grove	Industrial	87	Clearcut	No	none	
Forest Grove	Industrial	67	Clearcut	Yes	SN	
Forest Grove	Industrial	111	Clearcut	Yes	MF	
Forest Grove	Industrial	120	Clearcut	Yes	LF, SF	
Forest Grove	Industrial	40	Clearcut	No	SN	
Forest Grove	Industrial	66	Clearcut	Yes	SF	
Western Oregon	Industrial	27	Clearcut	Yes	LF, MF	
Western Oregon	Non-industrial	59	Clearcut	No	SN	
Clackamas-Marion	Industrial	33	Clearcut	Yes	SF	
Clackamas-Marion	Industrial	27	Clearcut	No	SN	
Clackamas-Marion	Industrial	86	Clearcut	No	SN	
Clackamas-Marion	Non-industrial	25	Clearcut	No	SF	
Clackamas-Marion	Industrial	89	Clearcut	No	SN	
Clackamas-Marion	Non-industrial	68	Clearcut	None	none	
Clackamas-Marion	Non-industrial	30	Clearcut	No	SN	
Clackamas-Marion	Non-industrial	25	Clearcut	No	SN	
Clackamas-Marion	Industrial	97	Clearcut	No	SN	
Clackamas-Marion	Non-industrial	30	Clearcut	No	none	
Clackamas-Marion	Industrial	30	Clearcut	No	LF	
Clackamas-Marion	Industrial	66	Clearcut	Yes	MF, MN	
Clackamas-Marion	Non-industrial	25	Clearcut	No	SF	Lake?
Clackamas-Marion	Industrial	40	Clearcut	No	none	
Clackamas-Marion	Industrial	92	Clearcut	Yes	SF	

[1] The MF portion of this stream was not surveyed. Enough trees were accounted for within the MN portion of the stream to confirm compliance.