Evaluation of Western Gray Squirrel Nesting Activity on Forest Practice Sites Subsequent to Harvest in Klickitat County, Washington

Final Report

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December 2000

EVALUATION OF WESTERN GRAY SQUIRREL NESTING ACTIVITY ON FOREST PRACTICE SITES SUBSEQUENT TO HARVEST IN KLICKITAT COUNTY, WASHINGTON

Funded by: the Cooperative Monitoring, Evaluation, and Research Program, Washington Department of Fish and Wildlife, and International Paper Company.

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This document was prepared under the auspices of the Cooperative Monitoring, Evaluation, and Research Committee of the Timber/Fish/Wildlife (TFW) Agreement. The TFW Agreement was reached in 1987 by representatives of the timber industry, state agencies, Indian tribes, and environmental groups with interests in, and responsibilities for, timber, fish, wildlife, and water resources in the State of Washington. It is a unique effort to manage public resources on state and private forest lands of Washington by consensus of constituents and interest groups representing historically disparate interests.

SUMMARY

The western grey squirrel (*Sciurus griseus*) inhabits oak/conifer forests in California, Oregon, and Washington. In Washington, the western grey squirrel currently exists in only three locations (Puget Sound, Chelan and Okanogan Counties, and Klickitat County), its range severely reduced from historical times by loss of suitable habitat. This reduction in habitat combined with an uncertain future for the extant populations prompted the Washington Department of Fish and Wildlife to list the species as state-threatened in 1993.

Harvest of timber within the occupied range of the western grey squirrel has the potential to degrade habitat by removing mast-producing trees, destroying nests and potential nest sites, and decreasing the interconnected tree canopy that squirrels use to travel safely through their territories. Beginning in the mid-1980s, western gray squirrel habitat in south-central Washington has been logged at an accelerated rate to salvage beetle and drought-killed ponderosa pine (*Pinus ponderosa*). To address this threat, the Washington Forest Practices Board established voluntary guidelines for commercial harvest within areas occupied by western grey squirrels. These guidelines were designed to protect existing nest trees and provide for retention of mast-producing trees and corridors to water sources within sites used by squirrels.

In spring of 1999 we began revisiting sites that had been harvested under approved forest practice applications for the purpose of documenting post-harvest nesting activity by western gray squirrels. Our objective was to address two questions of direct relevance to current nest protection guidelines: 1) does timber harvest affect nesting activity of western gray squirrels?, and 2) are operators complying with the current voluntary guidelines? Our approach was to resurvey sites that had been surveyed in prior years and document the change in number of active nests. We resurveyed 10 sites that had been surveyed for western gray squirrels and subsequently harvested for timber, and 10 sites that had been surveyed but not harvested for timber. All nest trees on post-harvest sites were evaluated for quality of protection according to nest protection guidelines. All sites were located within the Klickitat River drainage in south central Washington.

We found considerable change in the number of western gray squirrel nests on some sites over time, revealing the dynamic nature of nesting activity, and by association squirrel populations, on the landscape. The number of active nests changed substantially on some sites, but the changes were not consistent in direction on either the harvest or the control sites. However, the magnitude in number of active nests that decreased between surveys was greater on harvest sites than on controls. Substantial decreases ($\geq$50%) occurred for 4 harvest sites, but for no control sites, when sites with $\geq$10 active nests in the original survey were considered. These finding suggest that timber harvest had a negative effect on squirrel nesting activity on some sites.

The most definitive data set for examining the potential effect of nest protection on continued nesting activity included only nest trees that were clearly marked during the initial,

pre-harvest survey and identified as such during the resurvey. In this data set, 108 trees had received good protection, 78 received fair protection, and 93 received poor protection during timber harvest. Active nests were found predominantly in nest trees that had received good or fair protection. A comparison of the proportion of marked nest trees with active nests among trees provided with good or fair protection vs those provide poor protection revealed that nests with poor protection are less likely to receive continued use by western gray squirrels within the 1-3 year time frame considered in this study.

Examination of nests marked during pre-harvest surveys revealed that operators frequently were not complying with nest protection guidelines specified in individual forest practice permits. In some cases the violations appeared to represent obvious disregard for the nest protection measures (e.g., removal of large pine trees in close proximity to nests), whereas in others the violations were less flagrant. For example, fair or poor ratings for many of the nest trees on one site resulted from understory thinning of young trees within the 50-ft buffer. Situations such as this may have resulted from a misunderstanding on the part of the operator rather than a disregard for the guidelines. Regardless of cause, there is obviously much room for improvement in nest protection measures.

This study has provided a first look at conditions on sites harvested under western gray squirrel protection guidelines and the findings should be considered preliminary. This was largely an observational study; we had no experimental control over the placement of stands or when they were harvested, and we did not have the opportunity to match similar treatment and control sites and follow changes over the same set of years, as might be done in an impact assessment study. Future research should focus on a controlled study measuring the demography of the populations on each site and how it changes over the years, with detailed measurements of annual survival and productivity, as well as immigration and dispersal.

INTRODUCTION

The western grey squirrel (*Sciurus griseus*) inhabits oak/conifer forests in California, Oregon, and Washington. Relatively little is known about the ecology of the western grey squirrel and much of our existing knowledge comes from south in the species' range where habitat is very different from that in Washington and north-central Oregon. Studies in Oregon and California have been largely descriptive, with quantitative data based largely on small sample sizes (Ingles 1947, Cross 1969, Gilman 1986, Foster 1992). Most work in Washington has examined population distribution and has focused on locating nest sites, with little work on other aspects of western grey squirrel ecology (Bowles 1921, Barnum 1975, Rodrick 1986, WDFW unpublished report). Recent research on the Klickitat State Wildlife Recreation Area (KWRA) has provided new information on movements and habitat use by this species in Washington (Linders 2000). Findings from these studies and from ongoing research in Washington (WDFW unpublished data) suggest several components as critical to western grey squirrel habitat: 1) stands of large, mast-producing ponderosa pine (*Pinus ponderosa*), 2) clusters of mature conifer trees with interconnecting crowns for nesting, 3) mature Oregon white oaks (*Quercus garryana*), or other cavity forming trees, for natal den sites, 4) hypogeous fungi, and 5) free-standing water.

Western gray squirrels depend on tree nests for protection from predators and for shelter from the elements. They typically use three types of nest: spherical stick nests (shelter nests), platform stick nests, and cavity nests. Stick nests are usually placed in large conifer trees and are created by weaving together terminal branches clipped from conifers (Grinnell and Storer 1924). Newly created nests, and nests that have had new material added to them recently, contain branches with green or red needles that distinguish them from older nests that contain only brown material. Occasionally, stick nests are placed in oak trees or other hardwoods, and part or all of the material for these nests may derive from the host tree. Platform nests are thought to be used for diurnal loafing, whereas shelter nests are used for shelter both day and night and are sometimes used by lactating females and their dependent young. In some areas, pregnant females and females with young use cavities in oaks or other hardwoods (Grinnell and Storer 1924, Linders 2000).

In Washington, the western grey squirrel currently exists in only three locations (Puget Sound, Chelan and Okanogan Counties, and Klickitat County), its range severely reduced from historical times by loss of suitable habitat (Rodrick 1993). This reduction in habitat combined with an uncertain future for the extant populations prompted the Washington Department of Fish and Wildlife (WDFW) to list the species as state-threatened in 1993. Current threats to western grey squirrel habitat in Washington include: harvest of mast-producing softwoods, conversion of ponderosa pine and oak woodlands to Douglas fir *(Pseudotsuga menzeisii)* stands through silvicultural practices and fire suppression, clearing of ponderosa pine and oak woodlands for suburban and urban development, and habitat fragmentation. Biological threats to western grey squirrel populations include: loss of mast-producing softwoods to pine beetle infestations, invasion by potential competitors including California ground squirrels (*Spermophilus beecheyi*),

introduced eastern grey squirrels, (*S. carolinensis)*, and introduced wild turkeys (*Meleagris gallopavo*), and mange epidemics such as those documented in the early and mid 1900s and more recently in Klickitat County in 1998 (Cornish et al. 2001).

Beginning in the mid-1980s, western gray squirrel habitat in south-central Washington has been logged at an accelerated rate to salvage beetle and drought-killed ponderosa pine. Harvest of timber within the occupied range of the western grey squirrel has the potential to degrade habitat by removing mast-producing trees, destroying nests and potential nest sites, and decreasing the interconnected tree canopy that squirrels use to travel safely through their territories. Timber harvest can decrease numbers of tree squirrels and is believed to be a factor in declining western gray squirrel populations in north-central Oregon (Foster 1992). In a controlled experiment in Arizona, Patton et al. (1985) found lower densities of Kaibab squirrels (*S. aberti kaibabensis*) in ponderosa pine stands harvested for timber compared to unharvested control stands, despite harvest restrictions that maintained a buffer around nest trees.

To address the threat that timber harvest might pose to western gray squirrels, the Washington Forest Practices Board established voluntary guidelines for commercial harvest within areas occupied by the species in Klickitat County (WDNR 1996). These guidelines were designed to protect existing nest trees and provide for retention of mast-producing trees and corridors to water sources within sites used by squirrels. These voluntary guidelines currently provide the only protection for western grey squirrel habitat on timberlands in Washington. Pre-harvest surveys for arboreal stick nests are required for forest practice applications (FPAs) in Klickitat County. Surveys are conducted by WDFW biologists or by independent contractors or employees of the timber company who have undergone specific training. The area habitat biologist (WDFW) is responsible for entering language into the FPA that dictates how nests should be protected on the site. Generally, nest protection is considered in the harvest plan in accordance with a set of standard nest protection guidelines (Table 1). The habitat biologist has latitude when applying the standard guidelines and may choose to modify them after considering the nest survey results, condition of the forest stands, and the concerns of the landowner. For example, a dense cluster of nests in one stand might be put off limits to entry as a protected "set aside" in exchange for more lax canopy cover requirements in another part of the harvest unit that contains only scattered nests.

The protocol for nest surveys has changed slightly over the years, primarily in the quantity of data collected. Current protocol requires that both the condition and the color of each nest be recorded. These two characteristics yield insight as to the status of the nest. Nests in good condition suggest that they are currently in use, whereas nests that have lost some material or appear to be falling from the tree suggest an abandoned nest. Nests containing conifer branches with green or red needles indicate recent use, as this newly clipped material is added to the nest as part of new construction or maintenance. This information has been included in most surveys since 1997 but was provided only sporadically in earlier years. WDFW has also surveyed numerous sites in Klickitat County not associated with proposed timber harvests to

document the extent of occupied habitat (Rodrick 1999). These surveys focused on areas deemed to have suitable habitat and were completed in a manner similar to pre-harvest surveys.

Although the nest protection guidelines have been in effect since 1996 and have influenced harvest prescriptions on numerous sites, their efficacy for retaining nesting habitat for western grey squirrels has not been examined. In spring of 1999 we began revisiting sites that had been harvested under approved FPAs that included the nest protection guidelines for the purpose of examining post-harvest nesting activity by western gray squirrels and documenting operator compliance. This effort was expanded later in 1999 and in 2000 to include a total of 20 sites.

Table 1. Standard guidelines for protecting western gray squirrel habitat in Washington

1) protect all squirrel nests and nest trees
2) maintain a no-cut buffer within 50 feet of each nest tree
3) retain at least 50% canopy coverage within 400 feet of each nest tree
4) maintain arboreal "stringers" of trees between nests and nearby water sources and to foraging habitat
5) retain all oaks whenever possible
6) avoid logging, road building, or other noisy activities within 50-400 ft of all nest trees during the western gray squirrel breeding season.

Research questions and hypotheses

This study addressed two questions of direct relevance to current nest protection guidelines:

1) Does timber harvest affect nesting activity of western gray squirrels?

2) Are operators complying with the current voluntary guidelines?

To explore the first question we tested three null hypotheses:

$\mathbf{H_{01}}$: The number of western gray squirrel nests does not differ on sites before and after timber harvest

$\mathbf{H_{02}}$: The number of western gray squirrel nests on unharvested control sites does not change over a 1-3 year period.

H_{03}: Level of protection provided individual nests trees does not influence their value as nest trees.

To explore the second question, we examined operator compliance on sites harvested under the voluntary guidelines.

Study design

Our approach in this study was to compare the number of nests from surveys conducted before and after timber harvest on sites where the voluntary nest protection guidelines were included as part of the forest practice permit. A significant decrease in the number of nests present on sites in the years following harvest might indicate a negative effect of timber harvest on nesting activity. It is important to note that compliance with the voluntary guidelines would surely vary among sites; therefore, when comparing the number of nests before and after harvest, we were examining the effects of timber harvest *as it is currently practiced*—not the efficacy of the current guidelines. Thus, reduced nesting activity on harvested stands also may be related to non-compliance by operators, or inability of the operators to effectively implement the guidelines. Further, because timber harvest is only one of several potential factors influencing nesting activity, and to account for possible regional fluctuations in squirrel numbers, we duplicated the survey effort on a sample of sites that were not subjected to timber harvest. Differences in nest numbers on harvested sites that were not reflected in changes on unharvested (control) sites might then be more appropriately attributed to timber harvest.

Stick nests remain visible in the tree canopy after being abandoned by squirrels; we therefore needed some way to account for the gradual accumulation of nests that may be expected to occur on a site over a span of years. Active nests, those still in use, can best be identified by their condition (integrity) or by the presence of red or green material indicating recent maintenance (M. Linders, personal communication). Nest condition was not recorded in many of the earlier surveys, whereas presence of colored material was consistently noted. Therefore, we used the color of nests as an indicator of activity in both the original and resurveys, realizing that this would yield a conservative estimate of the number of active nests on a site.

METHODS

Site selection

We resurveyed 10 sites that had been surveyed for western gray squirrels and subsequently harvested for timber (table 2), and 10 sites that had been surveyed for western gray squirrels but not harvested for timber (table 3). All sites were located within the Klickitat River drainage in south-central Washington.

We identified potential study sites by reviewing survey records on file with WDFW in Olympia and by consulting with the area habitat biologist. All sites were a mix of ponderosa pine and Douglas fir, with patches of Oregon white oak. To be considered suitable, sites had to meet the following criteria:

1) $\geq$ 10 nests recorded on the initial survey, (we considered 10 nests the minimum number to indicate an active colony that would be likely to persist on the site),

2) between 80 and 300 acres in area,

3) survey records included a.) a map showing the boundaries of the area surveyed and general locations of nests, b.) documentation of the total number of nests, c.) indication of how many nests contained green or red material, and d.) dates the site was surveyed,

4) for post-harvest sites, a minimum of 1 year must have elapsed since harvest.

Sites meeting these criteria were visited to check if they had actually been harvested and to check for potential access problems. An insufficient number of sites met the above criteria, so we broadened the allowable size range to include sites less than 80 acres as long as they contained $\geq$ 10 nests. Although surveys conducted prior to 1997 did not require recording of nest condition or color, some surveyors consistently recorded nest color making these earlier surveys suitable.

Surveys

We consulted the survey records for each site to determine the boundaries of the original nest survey. Coverage of our resurveys was similar to that on the original surveys, focusing on mature stands likely to contain nests and avoiding areas of young regeneration. In several cases we contacted the original surveyor for additional information on the extent and intensity of the original surveys for specific sites. Several large sites were sub-sampled because of time constraints; only the nests within the sub-sampled area in both the original and resurvey were considered in our analyses. Sites were usually surveyed by walking along transects using a compass, but on steeper sites walking routes were along the contour of the slope. For each nest encountered on the survey we recorded type of nest (shelter or platform), condition of nest, color of material in nest, height of nest in tree, and diameter and species of the nest tree. Nest locations were marked on a map of the study site. We also noted direct observations of squirrels and other indicators of western gray squirrel activity such as foraging sign, as was done in the earlier surveys. All 20 resurveys were completed by a single, trained observer.

Nest trees located and recorded during earlier surveys were relocated during the follow-up survey using whatever means were available. On some post-harvest survey sites, nest trees were painted with numbers and bands around the trunk in a unique color. Markings ranged from relatively permanent paint through numbered flagging, to unnumbered flagging, to no markings

Table 2. Harvest sites sampled for western gray squirrel nesting activity, Klickitat County, Washington.

Site Name	Legal Description	Acres Harvested	Acres Surveyed[a]	Date(s) of Survey[b] Pre-Harvest	Harvest Date	Date(s) of Survey[b] Post-Harvest
Soda Springs	T5N R14E S21 S1/2	240	170	14 Oct. - 14 Nov. 1996	1998	28 Apr. - 19 May 1999
Wide Sky FPA	T3N R13E S28 & 29	70	70	27 Sept. - 1 Oct. 1996	1997	20 May - 8 Jun. 1999
Squirrel #5	T5N R14E S4 T6N R14E S33	570	570	2 Jul. 1997	1998	9 Jun. - 13 Jul. 1999
Brickman FPA	T4N R13E S22	65	65	1 Apr. 1998	1998	27 Oct. - 3 Nov. 1999
Swale Canyon	T4N R14E S28 NW1/4	80	80	11 Jan. - 28 Mar. 1996	1996	9 Nov. - 19 Nov. 1999
Bowman Creek	T4N R14E S2 & 11	370	117	1 Nov. - 6 Nov. 1996	1996-97	9 Mar. - 21 Mar. 2000
Jackel FPA	T6N R14E S30 NE1/4	23	12	19 Dec. 1997	1998	5 Apr. - 6 Apr. 2000
Squirrel #4	T6N R14E S27, 28, 33, & 34	906	206	8 May 1996	1997	24 May - 1 Jun. 2000
Squirrel #2	T5N R14E S2, 3, 10, & 11	333	333	16 Apr. - 31 May 1996	1998	8 Jun. - 16 Jun. 2000
Kayser FPA				5 -14 Oct., Nov. & Dec.	1998	20 Apr. - 23 Jun. 2000
-Set Aside Area	T6N R14E S28 & 29	33	33	1995		
-WGS Mgmt Area B	T6N R14E S28 & 29	25	25			
-Gen. harvest area	T6N R14E S21, 28, & 29	362	22			

[a] Post-harvest survey.

[b] Surveys occurred within theses date ranges, but not necessarily on all dates.

Table 3. Control sites sampled for western gray squirrel nesting activity, Klickitat County, Washington.

Site Name	Legal Description	Acres Surveyed	Date(s) of Baseline Survey [a]	Date(s) of Follow-Up Survey [a]
Skookum Canyon	T4N R13E S11, 12, 13, & 14	195	15 Oct. -15 Nov. 1997	7 Dec. - 9 Dec. 1999
KWRA	T5N R14E S26, 27, 34,& 35 T4N R14E S3 NE1/4	80	21 Oct. 1997	7 Jan. - 21 Jan. 2000
Wahkiacus Canyon	T4N R13E S12	105	13 Nov. 1997	21 Dec.'99 - 26 Jan. '00
Mill Creek	T4N R15E S5, 7, & 8	40	12 Nov. 1995	22 Feb. - 24 Feb. 2000
Schilling Ranch	T4N R14E S29 & 30	50	21 Oct. 1995	29 Feb. - 3 Mar. 2000
Blockhouse Creek	T4N R15E S17,18, & 19	90	23 Oct. - 26 Oct. 1995	2 Mar. - 7 Mar. 2000
Hilton Spring	T4N R13E S29 & 30	34	3 Oct. 1996	23 Mar. 2000
Beeks Canyon	T5N R13E S24 & 25	50	1 Oct. 1996	11 Apr. - 12 Apr. 2000
Little Klickitat South	T4N R15E S19 & 30	58	27 Oct. 1995	19 Apr. 2000
Chiles	T4N R14E S23	97	6 Dec. 1995 - 3 Jan. 1996	4 May - 5 May 2000

[a] Surveys occurred within theses date ranges, but not necessarily on all dates.

all on some control sites. On the latter sites, some trees were relocated using the original survey maps and description of the trees, but generally positive identification was not possible. Where previously marked nest trees could be positively identified, information was recorded for the tree using the same number assigned during the initial survey. Where identity of marked trees was not discernible, the nest trees were assigned new identification, but with a note on the survey sheet indicating that the trees were marked from an earlier survey.

Several characteristics of nests trees and their surroundings were recorded to aid in our evaluation of operator compliance. A Moosehorn Coverscope was used to determine canopy coverage near nests in a few sample locations on each post-harvest survey site. After using the coverscope to establish a general range of values for the site, canopy coverage was estimated by visual observation, except where an especially compromised nest was found and an exact value for remaining canopy coverage seemed appropriate. To get a representative sampling of canopy coverage readings, canopy coverage was checked in eight locations (the four cardinal directions, plus four positions in between) 25 ft from the subject tree. The eight values were averaged and converted to a percentage figure. In documenting harvest activity within 50 ft of nest trees, only stumps from the most recent forest practice were counted. Several of the post-harvest survey sites had been logged in the last 50 years, and it was not unusual to find old stumps near nest trees. In some instances, the number of stumps near nests suggested a significant intrusion into the 50 ft buffers, but closer inspection showed that the stumps were all old, and no recent intrusion had actually occurred. Characteristics used to evaluate age of stumps were color of cut wood, looseness of bark, insect holes, decayed condition of interior wood, chainsaw marks and face cuts vs. rotary saw marks, stump height (indicating method of harvest), and presence of painted butt marks on sites where "take trees" were painted. Where nest tree damage resulted from harvest too close to the nest, nearby stumps were examined for signs of felling into nest trees. The location of face cuts indicate the direction trees were felled, and where nest tree damage was attributed to harvest activities, at least one stump was found showing evidence of felling close enough to have caused the damage.

Evaluation of nest protection

Nest protection on post-harvest survey sites was evaluated according to two sets of guidelines. One was the Standard Nest Protection Guidelines, established as a set of voluntary guidelines in 1996 for application to all forest practices that include western gray squirrel occupied sites. The other was the conditions for western gray squirrel protection detailed in the approved FPA for each site. These conditions are usually based on recommendations from a representative from WDFW. All nest trees were evaluated using both sets of guidelines. In some cases, the two sets of protection measures were the same; in the remainder of cases, the conditions attached to the FPA varied from the standard set of guidelines.

Standard guidelines.—All nest trees on post-harvest sites were evaluated for quality of protection according to the Standard Nest Protection Guidelines. This provided a uniform set of criteria that could be applied to all nest trees, independent of the conditions placed on individual FPAs. The protection rating for each tree would then be used to evaluate its influence on the

continued use of that tree for nesting by western gray squirrels. Evaluation of nest protection was weighted heavily on the condition of the nest tree and the condition of the 50 ft buffer. We used the following dichotomous key to rate each nest tree:

1. Has any harvest-related alteration occurred within 50 ft. of the nest tree?
   No --------->Go to 5.
   Yes -------->Go to 2.

2. Is there damage to the nest tree?
   Yes -------->Poor Protection
   No -------->Go to 3.

3. Is remaining canopy coverage within 50 ft. of the nest $\geq$ 60%?
   Yes -------->Go to 5.
   No --------->Go to 4.

4. Is remaining canopy coverage $\geq$ 40%?
   Yes -------->Go to 6.
   No --------->Poor Protection

5. Was a corridor of trees with interlocking branches maintained between the nest tree and other important habitat (where present before harvest)?
   Yes -------->Good Protection
   No --------->Fair Protection

6. Where remaining canopy coverage inside buffer is < 60% but $\geq$ 40%, was any existing connection to other important habitat via a corridor of interlocking branches maintained?
   Yes ------->Fair Protection
   No -------->Poor Protection

Guidelines specified in FPA.—We considered only nest trees that were clearly marked when evaluating compliance with the conditions stipulated in the approved FPA. This assessment process closely paralleled that for the standard nest protection guidelines. Where the site prescription was essentially the same as the standard guidelines, the results of the two evaluation processes also were the same. Where the site prescription differed significantly from the standard guidelines, compliance with the conditions of the FPA sometimes differed from the adherence to standard guidelines. Usually, variances allowed in individual FPAs effectively relaxed the requirements for protection, so on these sites, compliance ratings often were higher than nest protection ratings based on the standard guidelines.

We considered nest trees rated as "good" to be in compliance with the FPA, whereas nest trees rated as "fair" or "poor" were considered not to be in compliance. We assigned an overall compliance rating to each site based on the proportion of nest trees complying with the FPA. Sites where $\geq$90% of the nests trees complied earned a rating of "good"; those with 89-75% of

nest trees in compliance earned a rating of "fair"; and those with <75% of nest trees in compliance earned a rating of "poor". This system for rating compliance held the operator to a high standard for protecting nests at the site level, while also allowing for a moderate degree of unintentional error in protection of individual nest trees.

All data were recorded on standard survey data sheets and nest locations were marked on a topographic map of the site (Appendix A). Survey sheets and nest maps for all sites are on file with WDFW in Olympia. Nest locations will be entered into WDFW's Natural Heritage Database.

Data analysis

We used Wilcoxon's paired-sample test (Zar 1984) to test the null hypothesis of no change in the number of nests over time. We performed this test on harvested sites and also on control sites, first using only active nests and then using all nests. Wilcoxon's paired-sample test evaluates the change in number of nests for each site using ranked scores (Zar 1984). We used a Chi-square analysis with Yates correction for continuity to examine the influence of nest protection on continued use of trees for nesting by western gray squirrels. This analysis was limited to marked nest trees and compared the proportion of trees with active nests among those provided with good or fair protection and those provided poor protection. Operator compliance was evaluated by a general review of compliance rates on harvested sites and was not subjected to statistical analysis.

The Kayser site was divided in the FPA into three units, one of which was to be a "set aside" excluded from harvest activities. The two harvest units had different nest protection applied to the FPA: nest trees in "management area B" were to be protected similar to the standard nest protection guidelines, whereas the "general harvest area" received less restrictive guidelines. Only nest trees in "management area B" were included in the analysis of change in number of total nests and active nests. We decided not to examine compliance on the Kayser site after it became apparent that there was confusion as to the boundaries of the 3 management units that was not resolved before harvest began.

RESULTS

Change in number of nests

The number of western gray squirrel nests counted on harvest and control sites increased between surveys by 47 and 46%, respectively. We counted a total of 449 nests on harvest sites during our post-harvest surveys, compared to 305 nests counted on the same sites before harvest. On control sites, we counted 340 nests during our resurvey, compared to 233 on the original survey.

The direction and magnitude of change in number of nests varied greatly among individual sites, both for harvest (Table 4) and control (Table 5) sites. The range in number of

Table 4. Change in nest trees and number of nests on harvested sites over time.

	Original survey		Post-harvest survey				
Site Name	Number of Nest Trees	Number of Nests	Number of Nest Trees[a]	Number of Nests	No. of Marked Nest Trees Without Nests	Difference in Number of Nests	% Change in Number of Nests
Soda Springs	61	61	69	51	19	-10	-16
Wide Sky FPA	46	46	36	23	13	-23	-50
Squirrel #5	33	33	37	32	5	-1	-3
Brickman FPA	15	15	33	36	0	21	140
Swale Canyon	73	73	98	76	23	3	4
Bowman Creek	16[b]	16[b]	166	166	3	150	938
Jackel FPA	19	19	24	21	3	2	11
Squirrel #4	14[b]	14[b]	13	13	1	-1	-7
Squirrel #2	10[b]	10[b]	12	8	4	-2	-20
Kayser FPA							
-Set Aside Area	38	38	65	50	15	12	32
-WGS Mgmt Area B	17	18	20	23	0	5	28
-Gen. Harvest Area	15	16	15	16	0	0	0

[a] Includes marked trees that no longer have nests.

[b] Only nests plotted within the boundaries of the post-harvest survey were tallied for comparison purposes.

Table 5. Change in nest trees and number of nests on control sites over time.

	Original survey		Second survey				
Site Name	Number of Nest Trees	Number of Nests	Number of Nest Trees[a]	Number of Nests	No. of Marked Nest Trees Without Nests	Difference in Number of Nests	% Change in Number of Nests
Skookum Canyon	33	33	33	31	2[b]	-2	-6
KWRA	11	11	38	39	--[b]	28	255
Wahkiacus Canyon	18	18	23	22	--[b]	4	22
Mill Creek	15	15	13	13	--[b]	-2	-13
Schilling Ranch	12	12	69	70	--[b]	58	483
Blockhouse Creek	11	11	18	18	--[b]	7	64
Hilton Spring	23	23	17	17	--[b]	-6	-26
Beeks Canyon	10	10	19	20	--[b]	10	100
Little Klickitat South	30	30	16	16	--[b]	-14	-47
Chiles	70	70	94	94	--[b]	24	34

[a] Includes marked trees that no longer have nests.

[b] Previously marked trees could not be relocated in most cases on this site.

nests (10-73) counted on the original surveys was similar on harvest and control sites, as were the median values for change in the number of nests between surveys (0.5 and 5.5, respectively). Results of the Wilcoxon's paired-sample test revealed no significant difference between number of nests counted in the original surveys compared to the number counted in resurveys for both the harvest ($T = 22.5$, n = 10, $P > 0.5$) and control ($T = 14$, n = 10, $P > 0.1$) sites. Clearly, the number of nests changed substantially on some sites, but the changes were not consistent in direction in either data set.

All but one of the harvest sites had marked nest trees that no longer contained a nest (table 3). For several sites this number was substantial, exceeding 25% of the trees originally marked. Similar figures are not available for control sites, because few nest trees were marked sufficiently well to be recognizable during the resurvey.

Change in number of active nests

We counted a total of 213 active nests on harvest sites during our post-harvest surveys, compared to 102 active nests counted on the same sites before harvest. On control sites, we counted 136 active nests during our resurvey, compared to 101 on the original survey. The ranges in number of nests counted on the original surveys were similar on harvest (4-22) and control (1-36) sites, as were the median values for change in the number of nests between surveys (-3 and 1, respectively).

Similar to our findings for number of total nests, the direction and magnitude of change in number of active nests varied greatly among individual sites, both for harvest (table 6) and control (table 7) sites. Results of the Wilcoxon's paired-sample test revealed no significant difference between number of active nests counted in the original surveys compared to the number counted in resurveys for both the harvest ($T = 20$, n = 10, $P > 0.5$) and control sites ($T = 21.5$, n = 10, $P > 0.5$). Clearly, the number of active nests changed substantially on some sites, but the changes were not consistent in direction in either data set. Unlike the changes in number of total nests, however, the magnitude in number of active nests that decreased between surveys was greater on harvest sites than on controls. Substantial decreases ($\geq$50%) occurred for 4 harvest sites, but for no control sites, when sites with $\geq$10 active nests in the original survey were considered.

The proportion of nests identified as active (i.e., containing new plant material) averaged between 36 and 43% on both the initial surveys and the resurveys of harvest and control sites. Similar mean values for control sites in both surveys suggest that these values represent what we might expect to occur, on average, across the landscape. At the site level, the proportion of active nests was more variable, ranging from 12-69% and from 8-55% on control sites for initial and resurveys, respectively, whereas values for individual harvest sites varied from 7-100% and from 0-69% for initial and resurveys, respectively.

Table 6. Change in number of active nests on harvested sites over time.

Site Name	Number of Active Nests[a] Original Survey	Post-Harvest Survey	Difference in Number of Active Nests	% Change in Number of Active Nests
Soda Springs	22	10	-12	-55
Wide Sky FPA	17	3	-14	-82
Squirrel #5	14 (2)[b]	7	-7	-50
Brickman FPA	6 (1)	21	15	250
Swale Canyon	5	21	16	320
Bowman Creek	14[c]	114	100	714
Jackel FPA	4 (1)	4	0	0
Squirrel #4	14[c]	0	-14	-100
Squirrel #2	6[c]	3	-3	-50
Kayser FPA				
-Set Aside Area	17 (8)	17	--[d]	--[d]
-WGS Mgmt Area B	1 (5)	4	--[d]	--[d]
-Gen. Harvest Area	7 (1)[c]	5 (1)	--[d]	--[d]

[a] Nests with green or red plant material

[b] Number in parenthesis is the number of nests for which color was either not recorded or could not be determined.

[c] Only nests plotted within the boundaries of the post-harvest survey were tallied for comparison purposes.

[d] Not suitable for analysis.

Table 7. Change in number of active nests on control sites over time.

Site Name	Number of Active Nests[a] Original Survey	Second Survey	Difference in Number of Active Nests	% Change in Number of Active Nests
Skookum Canyon	18	11	-7	-39
KWRA	5	27	22	440
Wahkiacus Canyon	9	9	0	0
Mill Creek	7	9	2	29
Schilling Ranch	1	21	20	2000
Blockhouse Creek	6	10	4	67
Hilton Spring	6	2	-4	-67
Beeks Canyon	2 (1)[c]	4	2	1
Little Klickitat South	11 (2)	8	-3	-27
Chiles	36 (3)	35	-1	-3

[a] Nests with green or red plant material

[b] Unharvested unit.

[c] Number in parenthesis is the number of nests for which color was either not recorded or could not be determined.

Nest condition as a function of protection class

The most definitive data set for examining the potential effect of nest protection on continued nesting activity included only those nest trees that were clearly marked during the initial, pre-harvest survey and identified as such during the resurvey. In this data set, 108 trees had received good protection, 78 received fair protection, and 93 received poor protection (Appendix B). Active nests were found predominantly in nest trees that had received good or fair protection (Fig. 1). A comparison of the proportion of marked nest trees with active nests among trees provided with good or fair protection vs. those provide poor protection revealed that nests with poor protection are less likely to receive continued use by western gray squirrels within the 1-3 year time frame considered in this study ($X^2 = 4.68$, df = 1, $P = 0.031$).

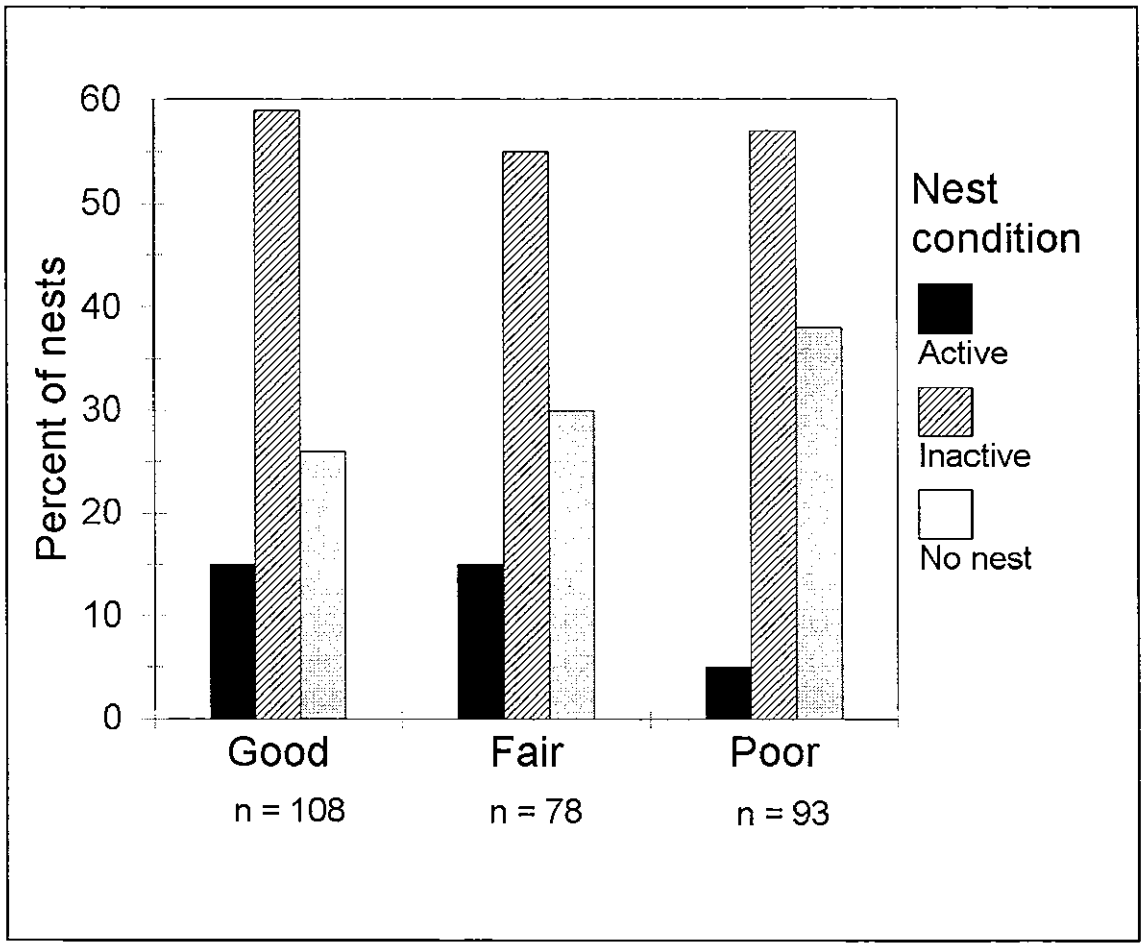

Figure 1. Condition of western gray squirrel nests (active, inactive, or not present) by protection class following timber harvest in nest trees marked during pre-harvest surveys, Klickitat County, Washington

In a second, broader analysis, we used all nests on harvested sites regardless of whether they were marked as having contained nests in the pre-harvest surveys. Some of these nests were built subsequent to harvest activities, and therefore their protection rating does not reflect effort to protect individual nest trees. Marked nest trees lacking nests were excluded from this analysis. Of 479 nests used in this analysis, 176 occurred in trees with good protection, 148 in trees with fair protection, and 155 in trees with poor protection. The distribution of inactive nests among protection classes was similar to that seen in the previous analysis using only marked nests, whereas the pattern for active nests revealed no protection class as dominant (Fig. 2). The more even distribution of active nests across the three protection classes may be explained by the addition of 200 unmarked nests, many of which likely were created post-harvest. New nests on harvested sites were not necessarily in areas protected from removal of individual trees, hence the 50 ft buffers surrounding the nest trees were likely to encompass some level of harvest activity.

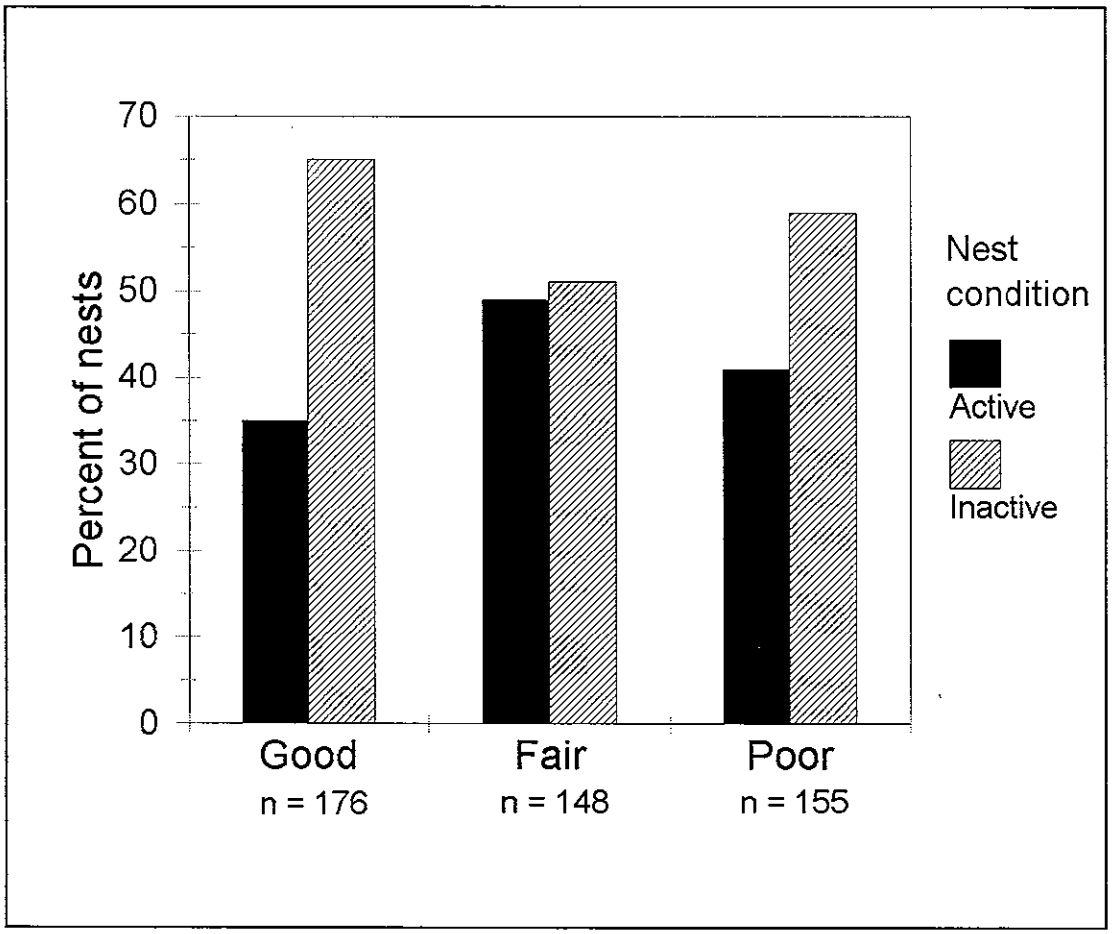

Figure 2. Condition of western gray squirrel nests (active or inactive) by protection class in all nest trees examined during post-harvest surveys, Klickitat County, Washington.

Assessment of operator compliance

Average compliance with nest protection guidelines stipulated in individual forest practice applications for each site varied from good to poor (Table 8). Two sites scored a good rating; the Brickman site which was helicopter logged, and the Jackel site on which close spacing of most nests resulted in almost no harvest in that part of the site containing nests. On these sites no 50 ft buffers were entered, or if they were, the nest tree remained intact and sufficient trees remained within the buffer to offer suitable canopy closure and protection of the nest tree. Six of the 9 sites earned a rating of poor, with an average compliance rate of 43% (range 14-67%).

Most sites had at least 1 tree that received a poor rating and for four sites the proportion of nests rated as poor was substantial (> 30%). Only the Brickman site received good ratings for all marked nest trees.

Table 8. Compliance with western gray squirrel nest protection guidelines as described in forest practice application for each site, Klickitat County, Washington.

Site	Protection rating for marked nests			Nest trees in compliance (%)[a]	Damaged marked nest trees	Average rating for site[b]
	Good	Fair	Poor			
Soda Springs	27	15	9	53	2	Poor
Wide Sky	9	7	8	38	1	Poor
Squirrel #5	5	19	11	14	0	Poor
Brickman FPA	15	0	0	100	0	Good
Swale Canyon	30	16	22	44	6	Poor
Bowman Creek	2	2	1	40	0	Poor
Jackel FPA	18	1	0	95	0	Good
Squirrel #4	4	2	0	67	0	Poor
Squirrel #2	5	0	1	83	0	Fair

[a] Nest trees with a "good" protection rating.
[b] Good = ≥90% of nest trees in compliance; Fair = 75-89%; Poor = <75%.

DISCUSSION

We found considerable change in the number of western gray squirrel nests on some sites over time, revealing the dynamic nature of nesting activity, and by association squirrel populations, on the landscape. Substantial changes in local populations of western gray squirrels have been documented in California (Grinnell and Storer 1924, Asserson 1974) and in Oregon (Cross 1969, Foster 1992), with decreases attributed to clearcut logging, fire, and disease. Increased nesting activity on some sites in Washington likely reflects an increase in squirrel numbers, whereas on other sites the apparent increase in nests may be due to increased search effort in the resurvey. Although every attempt was made to repeat the effort expended in the original survey, we realize that biologists surveying an impending forest practice sometimes are pressed for time and may miss some nests. Resurveys were at least as rigorous as original surveys, so decreases in nesting activity noted in this study likely reflect real changes in nest numbers on the site. Substantial decreases were evident for several harvested sites, a pattern not reflected in the control sites. These finding suggest that timber harvest had a negative effect on

squirrel nesting activity on these sites. No active nests were found on the Squirrel #4 site during the resurvey, indicating possible extirpation of that population.

Although changes in squirrel numbers may be influenced by timber harvest, other factors such as disease, predation, and movements associated with changing food availability also influence local populations (Foster 1992). Changes in the landscape adjacent to our survey sites also may have influenced nesting activity and contributed to observed increases or decreases. Harvest activity and modification of stand structure could result in squirrels leaving an area and "packing" into adjacent habitat, as has been suggested for forest birds in industrial forest landscapes (Hagan et al. 1996). Conversely, disturbance from extended harvest activity on nearby sites could force squirrels to leave an otherwise suitable area. Examination of harvest activities adjacent to our sites revealed no consistent pattern. Four harvested sites, Squirrel No. 2, Squirrel No. 4, Squirrel No. 5, and Kayser, all were within a large block of timberland that has been undergoing intense harvest; nesting activity on three of these sites dropped considerably between surveys. However, nesting activity declined on two other harvested sites, Soda Springs and Wide Sky, and both were largely isolated from other forest practices. Harvest activity was limited or non-existent beyond the boundaries of the Bowman Creek harvest site, yet nesting activity increased on this site dramatically, as it did on several control sites that also had no forest practices nearby.

At the level of individual nest trees, our data from marked nest trees indicate a negative effect of timber harvest on their continued use by gray squirrels. Specifically, nest trees that were provided poor protection were less likely to have active nests than those provided good or fair protection. This suggests that current nest protection guidelines, when followed, are working to maintain at least some level of suitability of existing nest trees. The pattern of tree removal outside of the required 50-ft buffers around existing nest trees likely does not provide for many additional nest sites that would fit our criteria for "good" protection. This is indicated by the more even distribution of active nests found on post-harvest surveys among trees rated as having good, fair, and poor protection. However, given that the abundance of "good" nest trees available for use by squirrels on these harvested sites was unknown, these data are probably not a suitable measure of selection. In order to use these data to assess selection of nest sites with different protection ratings, we would need similar data from a set of random trees as a measure of availability. Such an analysis should be considered for future efforts.

Examination of nests marked during pre-harvest surveys revealed that operators frequently were not complying with nest protection guidelines specified in individual forest practice permits. In some cases the violations appeared to represent obvious disregard for the nest protection measures (e.g., removal of large pine trees in close proximity to nests), whereas in others the violations were less flagrant. For example, fair or poor ratings for many of the nest trees on one site resulted from understory thinning of young trees within the 50-ft buffer. Situations such as this may have resulted from a misunderstanding on the part of the operator rather than a disregard for the guidelines. Regardless of cause, there is obviously much room for improvement in nest protection measures.

A major assumption of our study was that the number of nests found on a site is correlated with population density. This relationship has not been investigated for western gray squirrels; however, Dodd et al. (1998) found a significant correlation between number of total nests and density of the closely related Abert squirrel (*Sciurus aberti*) in ponderosa pine habitats in Arizona. Because nest counts are currently used as an indicator of the importance of sites to western gray squirrels in Washington, it is critical that the relationship between nest numbers and squirrel numbers, as well as the general nesting ecology of western gray squirrels, be investigated.

This study has provided a "first look" at conditions on sites harvested under western gray squirrel protection guidelines and the findings should be considered preliminary. This was largely an observational study; we had no experimental control over the placement of stands or when they were harvested, and we did not have the opportunity to match similar treatment and control sites and follow changes over the same set of years, as might be done in an impact assessment study. Moreover, assessing the effects of timber harvest on western gray squirrels at the stand level will require more than simply counting the number of active nests. Nest counts provide, at best, only an index to the number of squirrels and yield no information on the age or reproductive status of individuals inhabiting the site. Future research should focus on a controlled study measuring the demography of the populations on each site and how it changes over the years, with detailed measurements of annual survival and productivity, as well as immigration and dispersal. Such a study would yield a more complete picture of how timber harvest affects populations of western gray squirrels.

CONCLUSIONS

1. Use of stands for nesting by western gray squirrels is dynamic, increasing and decreasing from year to year as a result of various factors including timber harvest.

2. Level of protection afforded individual nests during harvest activities influences whether those nests continue to be used by western gray squirrels.

3. Compliance with nest protection guidelines dictated for individual FPAs was found to be poor on most sites.

4. More detailed research examining population parameters of squirrels on control and harvest sites, pre- and post-harvest, will be necessary to evaluate the full affects of forest practices on western gray squirrels.

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APPENDIX A

Western gray squirrel nest survey form and nest map.

WESTERN GRAY SQUIRREL SURVEY - DATA SHEET FOR NEST MAP

Attach data sheet to FPA or USGS map on which squirrel observations and nest locations have been mapped and numbered. If the survey covers more than one map, attach a SEPARATE data sheet to EACH map. See below for explanation of codes. A squirrel "observation" includes squirrels seen AND heard. If you observe a squirrel, mark the box with a LARGE X and use the comment field to indicate behavior, presence of young, etc. Also note if squirrel has mange or other physical problems.

DATE: 9 Mar.–21 Mar. 2000 **Location:** T 4N R 14E S 2

Write ONLY the township, range and sections that are shown on attached map

Surveyors: Susan Van Leuven–WDFW

(Names and affiliations — WDFW, Boise- Cascade, etc.)

Location Number on Attached Map	Sq. Obs. Here ?	Description Codes: Nest Type P/S/O	Nest Cond. A/B/C	Nest Color G/R/N	Nest Ht ft	Tree DBH In	Tree Spp P/F/O	Contact Name Address & Phone (to answer specific questions about this survey) / Comments
F FC		P	A	R	34	20	P	Conditions near this nest are the same as those at Nest FB.
F FD		P	A	N	33	14	P	C.C. within 50ft. of the nest tree is 45%; otherwise, conditions are the same as for Nest FB.
F FE		P	A	R	44	20	P	C.C. within 50ft of the nest tree is 45%; all other conditions are as for Nest FB.
F FF		P	A	R	40	14	P	Several small pines have been cut within 50 ft. of the nest tree. Connectivity is good; C.C. within 50ft. of the nest is 45%. C.C. 50–400 ft. away is 35%.
P FG		S	A	R	46	18	P	1 tree cut within a few inches of the base of the nest tree; a small pile of slash is nearby. C.C. near the nest is ~30%; C.C. 50–400 ft. away is 35–40%. Connectivity is good.
F FH		P	A	N	22	11	P	Many saplings cut within 50ft.

IF THERE ARE MORE THAN 20 OBSERVATIONS OR NESTS PLOTTED ON THE MAP, ATTACH A SECOND COPY OF THIS SHEET!

NEST TYPE:

P = Platform; flat nest usually made of conifer boughs (can include other materials such as oak, lichen, grass, etc.).

S = Shelter; spherical nest usually made of conifer boughs (can include other materials).

O = Oak or "summer"; bulky mass of oak twigs & leaves.

NEST CONDITION:

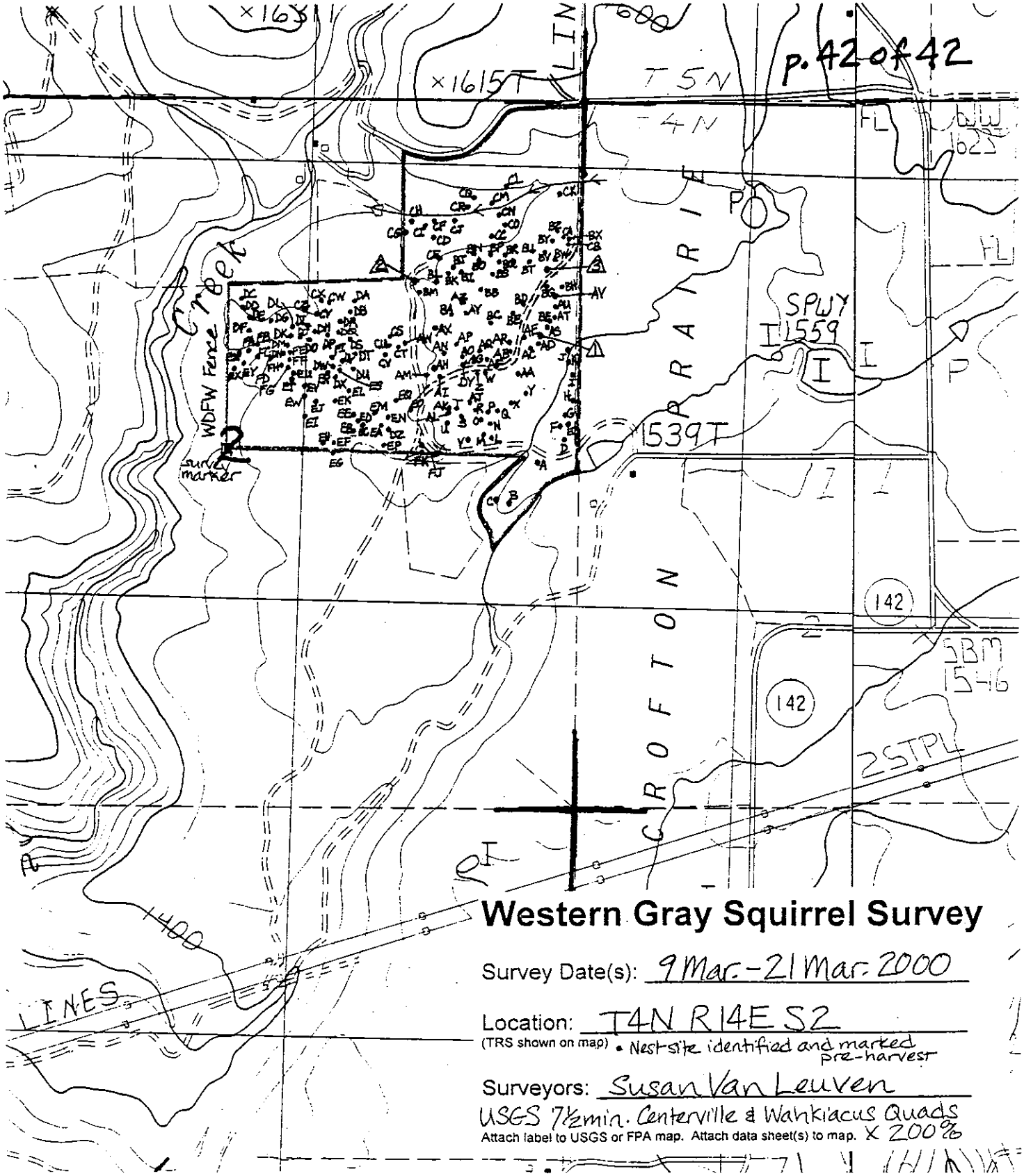
A = A fully constructed nest or a partially constructed nest that contains some fresh material

B = Nest apears to have lost material and is beginning to fall out of tree

C = Most material is gone, but material indicates western gray squirrel

NEST MATERIAL COLOR	TREE SPP
G: Green (any amount)	P: Pine
R: Red or Rusty (any amount, but no green)	F: Fir
N: Neither (brown/black)	O: Oak

Send survey package to: Julie Stofel, WDFW Wildlife Survey Data Management, 600 Capitol Way North, Olympia, WA 98501



Western Gray Squirrel Survey

Survey Date(s): 9 Mar.-21 Mar. 2000

Location: T4N R14E S2
(TRS shown on map) • Nest site identified and marked pre-harvest

Surveyors: Susan Van Leuven

USGS 7½min. Centerville & Wahkiacus Quads
Attach label to USGS or FPA map. Attach data sheet(s) to map. X 200%

APPENDIX B

Protection ratings for western gray squirrel nest trees assessed using Standard Nest Protection Guidelines, Klickitat County, Washington.

	Marked nest trees			Unmarked nest trees		
Site	Good	Fair	Poor	Good	Fair	Poor
Soda Springs	7	24	23	5	8	2
Wide Sky FPA	9	7	8	7	4	1
Squirrel #5	2	21	12	0	1	1
Brickman FPA	15	0	0	7	8	3
Swale Canyon	17	12	39	14	5	11
Bowman Creek	2	2	1	24	71	66
Jackel FPA[a]	18	1	0	4	1	0
Squirrel #4	4	2	0	3	2	2
Squirrel #2	4	1	1	3	0	3
Kayser FPA						
-Set Aside Area	25	5	6	24	2	3
-WGS Mgmt Area B	2	1	1	9	3	4
-Gen. Harvest Area	1	0	1	7	2	4

[a] Almost no harvest took place in unit containing squirrel nests because of close spacing of nests and overlap of 50m radius no-cut buffers.