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Distribution and Habitat of the Western Gray Squirrel (*Sciurus griseus*) on Ft. Lewis, Washington.

Abstract

Sciurus griseus has been accorded a "threatened" status by the Washington Department of Wildlife. Our objectives were to determine the distribution, abundance, and factors limiting the abundance of *Sciurus griseus* on Fort Lewis. Between June 1992 and August 1993 we conducted walking surveys for squirrels in 169 oak-conifer stands (approximately 700 ha). We observed 38 individual squirrels in 30 of the stands. We compared occupancy of oak stands by size, distance to water, and vegetation characteristics. We found that oak stands used by squirrels generally were: 1) > 2.0 ha, 2) < 0.6 km from water (lake, marsh, stream, or river), 3) on average, 34% *Quercus garryana,* 53% *Pseudotsuga menziesii,* and 13% other tree species, and 4) diverse in food-producing trees and shrubs including *Acer macrophvllum*, *Fraxinus latifolia*, and *Oemleria cerasiformis*. *Sciurus griseus* is associated with *Quercus garryana* woodlands which are dwindling due to human development. Fort Lewis holds the largest publicly-managed area of *Quercus garryana* in the Puget Sound region. In order to protect *Sciurus griseus* populations we recommend: 1) informing the public about *Sciurus griseus* and its status to reduce squirrel deaths by automobiles and 2) conserving and actively managing oak woodlands.

Introduction

Western gray squirrels *(Sciurus griseus)* are found in Washington, Oregon, California. and Nevada (Carraway and Vertz 1994). The State of Washington lists the western gray squirrel as "threatened" (Washington Department of Wildlife 1993). The western gray squirrel was once commonly seen in Oregon white oak (*Quercus garryana*) woodlands bordering prairies in river valleys in the Northwest (Bowles 1921). But these oak woodlands are being replaced by conifers, agricultural lands, and human dwellings and the squirrel exists in small, scattered populations in Washington.

Western gray squirrels inhabit three areas in Washington: Klickitat County along the southern Columbia River and its tributaries; in Okanogan and Chelan Counties in the northern Columbia River basin; and in the Puget Trough, in particular, Fort Lewis Military Reservation (Rodrick 1987: Figure 1). Because the U. S. Department of Defense gives special consideration in its land management to sensitive species, we studied the popoulation on Fort Lewis. The objectives of our study were to describe the distribution, abundance. habitat, behavior, and factors possibly limiting abundance of western gray squirrels on Fort Lewis.

Study Area

Fort Lewis lies in the Puget Trough between Olympia and Tacoma, in Thurston and Pierce Counties, Washington. It consists of approximately 34,400 ha of forests, prairies, wetlands, and developed areas. including 1,200 ha of Oregon white oak woodlands. Fort Lewis maps show > 400 distinct oak woodlands ranging in size from < 0.2 ha to > 44 ha (Figure 2). Oak woodlands are most commonly found adjacent to prairies, ponds, lakes, and marshes, and at the top or bottom of hills.

Methods

Distribution and Abundance

We used snaps of oak woodlands and reports of historical sightings of western gray squirrels to begin our study. First we tried to live trap squirrels, then we used walking surveys, to determine the distribution of squirrels.

Trapping. We located 10 areas on Fort Lewis where squirrels had been seen and set traps in them for a total of 4,162 trap nights from April 21 to September 4, 1992. We used wire box traps and several types of bait: peanut butter-oat mix, tuna cat food, candy bars, dried corn, whole cracked walnuts, pecan halves, and peanuts in the shell. Traps

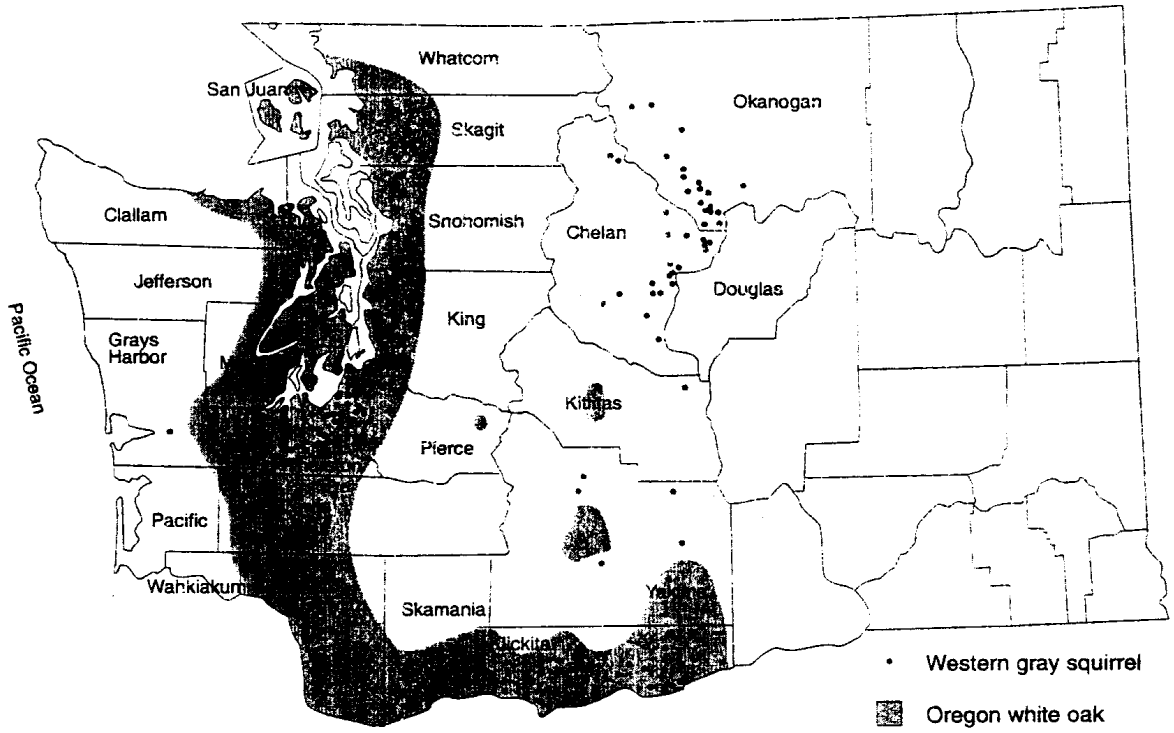

Figure 1. Distribution of *Sciurus griseus* (Rodrick 1986) and *Quercus garryana* woodlands (Stein 1990) in Washington.

were prebaited for 3 days prior to trapping. Initially, traps were placed on the ground, 30 m apart, in a grid pattern throughout the stands. After several weeks with no trapping success, we moved traps closer to the base of trees with stick nests, using no formal grid pattern. Only two squirrels were captured and we abandoned trapping as a method.

Surveys for Distribution. We conducted surveys on foot to determine the presence of western gray squirrels in 313 oak stands covering 910 ha on Fort Lewis from June 1992 to August 1993. We did not formally survey oak stands in artillery impact areas. housing areas, and developed areas because of lack of access and high human disturbance. We routinely saw eastern gray squirrels (*Sciurus carolinesis*), but not western gray squirrels, in the housing and business areas. Of the 313 stands visited, 85 were eliminated from further surveys because in our subjective evaluation they appeared unsuitable for western gray squirrels because of one or more of the following factors: 1) < 0.1 ha in size, 2) < 5 oaks, 3) within developed areas, and 4) > 500 m from adjacent conifers. In preliminary surveys in three stands known to have squirrels, squirrels were seen during 71% of visits to each stand, on average, and were active throughout the day. We concluded that 3 visits were sufficient to determine if squirrels were present in a stand. We intensively surveyed (3 surveys) 169 stands of the 228 remaining oak stands for squirrels on three different days between 0700 and 1630. Each stand was surveyed in its entirety by observers walking through the stands at 1.0-1.5 km per hour, pausing about every 15m to listen and search for squirrels. Observers recorded the time, location, and activities of squirrels seen or heard. A sighting was considered an independent observation if it was seen > 500 m from other sightings. This distance was an arbitrary distance chosen to prevent counting the same squirrel more than once. It is unlikely that we saw all squirrels present in each stand we surveyed.

We classified the oak stands into three groups based on the number of squirrel sightings in the stand. We assumed that consistency of detection reflected consistency of use. Stands were considered high use if squirrels were seen there consistently (≥ 67 % of visits) or if three or more squirrels were seen on any one visit.

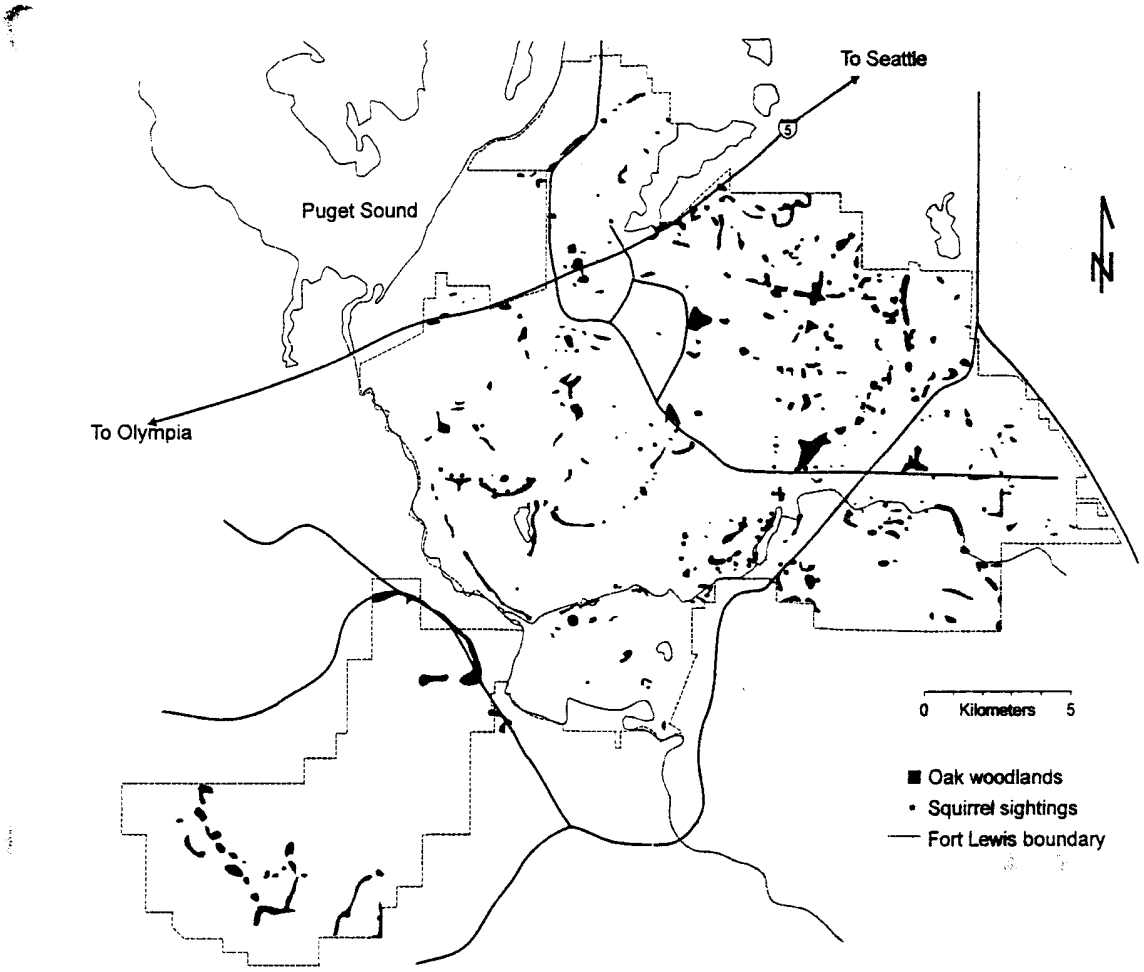

Figure 2. Locations of *Sciurus griseus* sightings (including road kills) and *Quercus garryana* woodlands (Fort Lewis Geographical Information Systems), Fort Lewis, Washington, 1992-1993.

We assumed that these stands had high use by western gray squirrels even though we rarely saw more than one squirrel per visit. Stands with one or two sightings over 3 visits were considered moderate use stands. The stands in a random sample of 26 surveyed stands in which no squirrels were seen were considered low-use. We could not assume that squirrels never used these areas. Thus, our classification relates as much to consistency of activity as to abundance or density of squirrels.

Describing Stands

For each of 30 stands in which squirrels were seen, we measured species composition, density, and basal area of trees and species composition and percent cover of understory vegetation. We also chose a random sample of 30 stands from the 139 surveyed stands in which squirrels were not seen; but, because of heavy military activity, only 26 of these stands were actually measured. Therefore, a total of 56 stands were measured.

We used the point-centered quarter (PCQ) method of vegetation sampling for trees (Cottam and Curtis 1956). We placed PCQ points throughout the oak and oak-conifer stand in a grid pattern, 15-50 m apart, depending on the size of the stand, in order to sample 15-30 points (60-120 trees) per stand. We kept points > 15 m from the edge of the stand to avoid edge effects. We used 10-25 1.5-m-radius plots systematically spaced throughout the stand to sample percent vegetation cover and dominant taxa for each of three life forms: 1) herbaceous: ferns, forbs, and grasses, 2) woody:

shrubs, and seedling and sapling trees < 4 m. and 3) understory trees > 4 m and < 10 cm diameter at breast height (DBH). We followed the taxonomy and nomenclature of Hitchcock and Cronquist (1991). We measured distance to water from squirrels and oak stands on 1:24,000 7.5 minute quadrangle maps and in the field when any unmapped water sources were found during surveys.

We calculated means for all variables measured in each stand, and then we averaged the means to determine means for each group of stands: high. moderate, and low use. As an exploratory analysis of features associated with gray squirrels, we compared the means for several variables in the three groups by using analysis of variance (ANOVA) and multiple range tests of variance (Duncan's and Student-Newman-Keuls). Although some protection from erroneous significance due to multiple comparisons is provided by the procedures supplementing the ANOVA, there is still a risk that differences appearing significant at any preferred p value are not. Additionally, the analysis was *post hoc* and exploratory; thus caution must be used in extrapolating our results and using them as predictors.

We classified each of the high, moderate, and low use stands by size (0.4-2.0 ha: 2.1-8.0 ha; > 8.0 ha) and distance from water (<0.1 km; 0.1-0.39 km; 0.4-0.69 km; 0.7-1.0 km; >1.0 km). To evaluate the influence of size and distance to water on use by western gray squirrels. we ran Chi-square tests on the number of stands in high, moderate, and low use groups in each size and distance class, reflecting our emphasis on consistency of use and our inability to measure abundance. This was a retrospective, exploratory analysis.

After recognizing that both the size of the stand and distance to water could be influencing the presence of western gray squirrels in a stand, we did an additional, prospective, experimental test to quantify these influences. We chose random samples of 10 stands, in each of 6 categories based on size and distance to water (a total of 60 stands). We surveyed each stand three times for squirrels and determined the number of stands in which squirrels were present. Two stands had to be recategorized following surveys because we found additional water sources there. One of these stands was also smaller than what was shown on the original oak stand map. This created unequal sample sizes. We performed Chi-square tests to compare western gray squirrel use of stands cross-classified by size and distance to water.

Behavioral Observations

The presence of squirrels at any specific location and the length of observable activity periods was unpredictable, so we did not do time-controlled activity budgets during this study. Rather, we opportuneistically recorded observations from August 1992 through August 1993. We approached oak stands with squirrels slowly and quietly, sat where we could see a large area of habitat, and recorded squirrel activities. We also recorded activities of all squirrels seen during walking and driving surveys and combined this information with data from behavioral observations to determine general seasonal behaviors. We grouped behaviors into seven categories: 1) foraging, 2) traveling, 3) resting and grooming, 4) agonistic interactions. 5) mating, 6) escaping and warning, and 7) alert and watching and determined the duration of activities for all observations. We compared proportions of time spent in each activity by season using pie charts. We compared relative time spent on the ground with time spent in trees using Chi-square tests.

Results

Distribution and Abundance

During 406 hours of surveys we saw 46 western gray squirrels, or 1 squirrel per 8.8 hours of survey time. These 46 sightings reflected at least 38 individual squirrels in 30 of the 169 stands surveyed. We intensely surveyed about 74% of the possible western gray squirrel habitat (228 stands) on Fort Lewis. We and Fort Lewis Forestry and Wildlife personnel documented 272 western gray squirrels observed outside of formal surveys from April 1992 to August 1993. When we mapped these locations, 43 individuals and 14 stands were added to the 38 individuals seen in 30 stands during surveys. Thus, approximately 81 individual western gray squirrels were seen from April 1992 to August 1993 in 44 separate oak stands. Of these 81, 13 were found dead on roads and two were found dead on the ground within an oak stand. The cause of death of the two squirrels in the oak stands was not

determined; there were no signs of injuries or predation. Most road-killed squirrels (11 of 13) were found from April to August; two were pregnant, a third was lactating, and four others were juveniles. Squirrels were seen most often in large oak-Douglas-fir stands near water (Figure 2). They were never seen in pure oak stands that were isolated from conifers and water. Eighty-four percent (267 of 318) of total western gray squirrel sightings were ≤ 390 m of a source of water. About 31 % of all oak stands were ≤ 390 m from water.

Habitat Characteristics-Post *Hoc* Comparisons

Oak stands on Fort Lewis were highly variable in the composition and abundance of forest-floor vegetation and shrubs and the density and abundance of tree species (Table 1). Stand size varied from 0.4 ha to 48 ha, while distance to water varied from < 0.1 km to > 1.0 km. Many plant species that produce squirrel food were rare, with an average percent cover of < 5% (Table 1), but were abundant in particular stands (10-20% cover), resulting in high variability in the average number of mast species per stand.

The characteristics of oak stands in our retrospective survey differed significantly between high and low use stands in terms of size of the stand. distance from water, tree species composition, basal area of stand, and understory plant species composition at the three life form levels (Table 2). Moderate use stands had some characteristics of both high and low use stands. High-use stands were larger (Table 3) and closer to water (Table 4) than low-use stands. High-use stands had an overstory with an average of 34% oak, 53% Douglas-fir, and 13% other tree species. Low-use stands had an average of 53% oak, 43% Douglas-fir, and < 5% other tree species. The relative frequency of Oregon white oak trees was significantly greater in low-use stands than in high-use stands. There was no significant difference in the relative frequency or the average DBH of Douglas-fir trees between high- and low-use stands but high-use stands had a significantly higher average basal area of Douglas-fir (Table 2). High-use stands had a greater diversity of tree species (16 species) than low-use stands (13 species) and greater abundances of bigleaf maple (*Acer macrophyllum*), Oregon ash (*Fraxinus latifolia*), bitter cherry (*Prunus avium*), cascara (*Rhamnus purshiana*), and western red cedar (*Thuja plicata*) than low-use stands. Some of the differences in diversity of tree species may be due to the differences in stand sizes (i.e., a species-area effect).

TABLE 1. Vegetation in 56 *Quercus garryana* woodlands on Fort Lewis. Washington. 1993.

Habitat Element	Mean	CV[1]	Range
HERBACEOUS PLANTS (% cover)			
Total	39	42	9 - 83
Forb	53	48	6 - 92
Grass	33	79	0 - 93
Moss	30	95	0 - 100
Fern	25	77	0 - 81
SHRUBS (% cover)			
Total	46	29	15 - 73
Cytisus scoparius	19	46	0 - 100
Berberis aquifolium	10	90	0 - 46
Holodiscus discolor	7	117	0 - 33
Berberis nervosa	4	113	0 - 40
Symphoricarpos albus	48	145	0 - 100
Corylus cornuta californica (< 4 m)	22	169	0 - 77
Oemleria cerasiformes	10	128	0 - 54
Pseudotsuga menziesii	8	147	0 - 54
Quercus garryana	5	254	0 - 27
Gaultheria shallon	4	216	0 - 64
Amelanchier alnifolia	3	278	0 - 21
Rosa gymnocarpa	1	250	0 - 14
Rubus procerus	1	370	0 - 18
Vaccinium ovatum	1	300	0 - 20
Ribes sp.	1	367	0 - 13
UNDERSTORY TREES (% cover)			
Total	8	84	0 - 32
Pseudotsuga menziesii	9	110	0 - 33
Quercus garryana	7	114	0 - 39
Acer macrophyllum	2	238	0 - 24
Corylus cornuta (>4.0 m)	2	265	0 - 23
Fraxinus latifolia	2	347	0 - 27
CANOPY			
Density (trees/ha)	225	158	12 - 440
% *Quercus garryana*	45	54	5 - 100
% *Pseudotsuga menziesii*	48	45	0 - 85
% Other trees	7		0 - 42
Basal area (m^2/ha)	21	46	0.8 - 44
Median DBH (cm) *Quercus garryana*	21	25	12 - 40
Median DBH (cm) *P. menziesii*	47	32	19 - 102

[1] Coefficient of variation expressed as a percent.

There were differences in vegetation in the three life form levels between high- and low-use oak stands. High-use stands had a higher percent cover of understory trees than low-use stands. The most common understory trees were bigleaf maple and Oregon ash. There was no significant differ-

TABLE 2. Characteristics of *Quercus garryana* woodlands with differential use[1] by *Sciurus griseus*, Fort Lewis, Washington, 1993.

Habitat feature	High use n=18		Moderate use n=12		Low use n=26		p-value
	Mean	(SE)	Mean	(SE)	Mean	(SE)	
# Food species[2]	8.3	(0.5)	6.4	(0.5)	5.6	(0.4)	0.00
DBH[4] QUGA[3]	21.5	(1.1)	21.7	(2.0)	25.9	(6.1)	0.51
DBH PSME	48.5	(2.1)	48.9	(6.4)	44.4	(2.7)	0.58
Trees/ha	243.8	(17.0)	216.7	(21.5)	215.3	(21.0)	0.56
% QUGA	34.1	(3.1)	43.6	(6.7)	52.5	(4.9)	0.03
% PSME	53.3	(3.3)	51.9	(6.6)	43.0	(4.9)	0.25
% other trees	12.6	(3.3)	4.5	(2.3)	4.8	(1.7)	0.03
BA[5] (all trees)	27.0	(2.0)	22.2	(2.6)	16.2	(1.8)	0.00
BA QUGA	4.1	(0.9)	3.9	(0.9)	3.9	(0.6)	0.97
BA PSME	29.0	(5.5)	21.7	(3.5)	14.4	(1.7)	0.02
% Ground cover	31.5	(2.8)	36.1	(5.7)	46.1	(2.9)	0.01
% Shrub cover	41.9	(1.8)	44.8	(4.1)	50.3	(3.1)	0.13

[1] High use = western gray squirrels were seen > 2 times or > 2 squirrels seen simultaneously; moderate use = squirrels seen 1 or 2 times; low use = squirrels never seen in stand.

[2] Food species include *Symphoricarpos albus*, *Corylus cornuta*, *Oemleria cerasiformes*, *Pseudotsuga menziesii*, *Quercus garryana*, *Gaultheria shallon*, *Amelanchier alnifolia*, *Rosa* sp., *Rubus procerus*, *Vaccinium parvifolium*, *Ribes* sp., *Acer macrophyllum*, *Acer circinatum*, *Fraxinus latifolia*, *Pinus ponderosa*, *Rhamnus purshiana*, *Taxus brevifolia*, *Abies grandis* *Cornus nuttallii*, *Populus trichocarpa*, and *Pyrus malus*.

[3] QUGA = *Quercus garryana*, PSME = *Pseudotsuga menziesii*.

[4] DBH = diameter at breast height in centimeters.

[5] Basal area in meters^2/hectare.

TABLE 3. A retrospective comparison[1] of the percent of oak stands across 3 size classifications for three samples of oak stands; 1) 18 stands with high western gray squirrel use; 2) 12 stands with moderate use; and 3) a random sample of 26 stands in which no squirrels were seen (low use); 56 stands total; Fort Lewis, Washington, 1992-1993.

Size[3]	Stand use[2]		
	High	Moderate	Low
1	22	25	**50**
2	**44**	**33**	**46**
3	**33**	**42**	4

[1] Statistical results: Pearson Chisquare = 10.354; df = 4; p = 0.035.

[2] High use = western gray squirrels seen in stand > 2 times or > 2 squirrels seen simultaneously; moderate use = squirrels seen in stand 1 or 2 times; low use = squirrels never seen in stand.

[3] Size classes: 1 = 0.4-1.9 hectares, 2 = 2.0-8.0 hectares, 3 = >8.0 hectares.

TABLE 4. A retrospective comparison[1] of the percent of stands across 5 distance-from-water classifications for 3 samples of Oregon white oak stands: 1) 18 stands with high western gray squirrel use, 2) 12 stands with moderate use, and 3) a random sample of 26 stands in which no western gray squirrels were seen (low use); Fort Lewis, Washington, 1992-1993.

Distance[2]	Stand use[3]		
	High	Moderate	Low
1	**44**	**42**	19
2	22	33	8
3	28	17	19
4	5	8	15
5	0	0	**38**

[1] Statistical results: Minimum expected value = 1.29, Pearson Chisquare = 18.94, df = 8, p = 0.015.

[2] Distance classes: 1 = < 0.1 km, 2 = 0.1-0.39 km, 3 = 0.4-0.69 km, 4 = 0.7-1.0 km, 5 = > 1.0 km.

[3] High use = western gray squirrels were seen in the stand > 2 times or > 2 squirrels were seen in the stand simultaneously; moderate use = squirrels seen in stand 1 or 2 times; low use = squirrels never seen in stand.

ence in total percent cover at the shrub level but species composition varied between high and low use stands. High-use stands had, on average, a greater variety of food-bearing trees and shrubs in the understory (Table 2) and these species, if present, occurred in greater abundance in high-use stands than in low-use stands. Indian plum (*Oemleria cerasiformes*) was significantly more abundant in high-use stands (p=0.020) while Scot's broom (*Cytisus scoparius*) was significantly more adundant in low-use stands (p=0.001).

High-use stands had significantly more understory oak than low-use stands suggesting more oak regeneration in these stands. At life form level one (forbs, ferns, grasses, and ground-cover), low-use stands had a greater percent of vegetation cover than high-use stands. High-use stands had more ferns (p=0.010) and mosses (p=0.008) at life form level one, while low-use stands had more grasses (p=0.020) and forbs (p=0.008). High-use stands had a higher percent cover of coarse woody debris (p=0.001) than low-use stands.

Variables we initially thought would be important to western gray squirrels, such as tree density, median DBH of oak, median DBH of Douglas-fir, percent Douglas-fir, percent shrub cover, and amount of hazel, did not vary significantly between high and low-use stands.

Stand Size and Distance to Water : A Test of an Hypothesis

The random sample comparison of the influence of size and distance to water confirmed that squirrels indeed preferred larger stands (> 8.0 ha) closer to water (< 0.6 km) than smaller stands further from water (Table 5). The hypotheses of no effects were rejected.

Behavior

We observed squirrels from one minute to five hours at a time. We were able to observe two groups (of 3-7 squirrels each) in two oak stands for 2- and 11-month periods and recorded their activities (Table 6). Primary activities varied seasonally (Figure 3). From November through March, squirrels spent most of their time traveling on the ground and

TABLE 5. Prospective comparison[1] (number of stands with squirrels/number of stands surveyed) of the number of surveyed Quercus garryana stands used by Sciurus griseus in 6 size/distance to water categories; 10 stands in each category were chosen randomly from all Quercus garryana stands on Fort Lewis, Washington, 1993.[2]

	Distance from water		
Size of stand	<0.6 km	> 0.6 km	Total
< 2 ha	0/10	0/10	0/20
2-8 ha	0/11	0/10	0/21
> 8 ha	6/11	0/8	6/19
Total	6/32	0/28	6/60

[1] Statistical results: Size x Squirrel X^2 = 15.73, df = 2, p = 0.0004; Water x Squirrel X^2 = 8.54, df= 1, p = 0.0035

[2] Upon subsequent field examination, two stands were recategorized; one was found tc be in a smaller size class and closer to water, and another was closer to water, making sample sizes uneven.

TABLE 6. Time (minutes) western gray squirrels spent at primary activities by month,[1] Fort Lewis, Washington, 1992-1993.

		Activity							
Month	Total time (minutes)	Forage	Travel	Rest	Agonistic	Groom	Watch	Warning/ Escape	Mate
January	34	4	27	3	0	0	0	0	0
February	227	67	98	14	19	12	5	12	0
March	168	23	103	2	6	2	0	32	0
April	202	83	46	18	10	4	3	38	0
May	542	2	236	55	208	12	12	13	4
June	38	0	9	0	24	0	4	1	0
August	1362	928	79	81	33	16	18	207	0
September	246	180	30	6	4	2	5	19	0
November	26	4	9	2	0	4	1	6	0
Total	2845	1291	637	181	304	52	48	328	4

[1] Less than 10 minutes of observations were collected in July, October, and December.

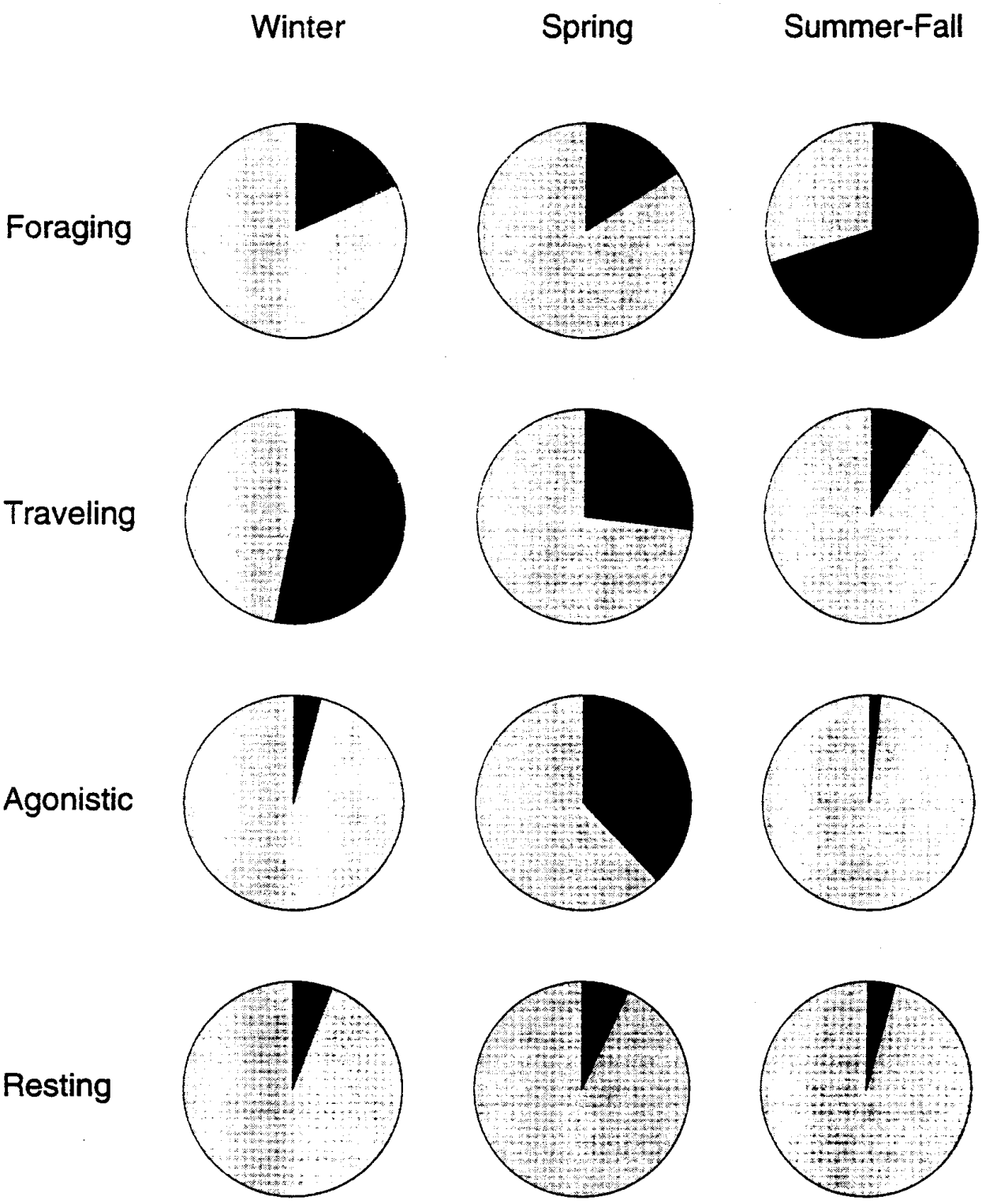

Figure 3. Relative time spent in major out-of-nest activities by *Sciurus griseus*, Fort Lewis, Washington, 1992-1993.

digging for and foraging on buried acorns. Travel decreased in late spring and early summer, then increased again in late fall. In April, May, and June. squirrels spent much of their time engaged in agonistic behavior with other western gray squirrels. Sexual behavior was observed in May. From July through October squirrels spent almost all of their out-of-nest time foraging.

The amount of time spent on the ground versus in trees varied significantly among seasons (Table 7). In spring and summer squirrels were seen considerably more often on the ground than in trees (oak and Douglas-fir). In fall and winter squirrels were seen in trees as often as on the ground. Sightings were naturally biased towards roads and the ground since squirrels are more readily seen in the open than in trees. Nevertheless, squirrels frequently traveled on and across roads; 17% (52 of 318) of all squirrel sightings were on paved roads. Twenty-five percent of squirrels seen on roads had been killed by automobiles. This compares with 40% of sightings on the ground, 22% in Douglas-fir, and 16% in Oregon white oak.

TABLE 7. Number of western gray squirrel sightings on the ground and in trees, by season, Fort Lewis, Washington. 1992-1993.

	Number of Sightings[2]	
Season[1]	Ground	Tree
Winter	49	51
Spring	70	30
Summer	57	43
Fall	52	48

[1] Winter: December-February, Spring: March-May, Summer: June-August, Fall: September-November.

[2] Statistical results: Minimum expected value = 19.42, Pearson Chisquare = 8.222, d.f. = 3, p = 0.042

Foraging, including picking, gathering, burying, and eating food items was the most common out-of-nest activity observed overall, especially in August and September when squirrels were gathering and burying acorns in preparation for winter. Squirrels buried each acorn in a separate hole on the ground under or near the source oak tree. In general, food items we saw western gray squirrels eating on Fort Lewis were: 1) spring—fungi, succulent vegetation, and Douglas-fir cambium; 2) summer—bigleaf and vine maple samaras, and indian plum berries: 3) fall—acorns, Douglas-fir seed, hazelnuts, and fungi; and 4) winter—acorns, hazelnuts, and maple samaras.

Discussion

Distribution and Abundance

Surveys proved effective in locating western gray squirrels and their habitat on Fort Lewis. It is unlikely that we saw all squirrels present in the oak stands we surveyed, but we were able to determine general patterns of distribution. Squirrel distribution followed water courses including streams, rivers, marshes, and lakes—as previously reported by the Washington Department of Wildlife (1993). This type of distribution has been reported for fox squirrels (*Sciurus niger*) in the southeastern United States (P. Weigl. pers. comm. 1994). Distribution of squirrels reflected the size of the oak stand and adjacency of the oak stand to other forests and to water. No squirrels were seen in isolated pure oak stands. Stand size is important in terms of 1) providing an adequate supply of food and nest sites for year-round occupancy; 2) allowing for occupancy of more than one squirrel (the larger the stand, the more squirrels, the greater chance of persistence, and the greater probability the stand will be found by dispersing squirrels); 3) opportunity for diversity in food sources. Adjacency of oak stands to Douglas-fir stands provides additional food and shelter and may provide corridors to other oak patches. Prairie-conifer forest ecotones and water courses are most likely the key dispersal routes for squirrels because squirrels rarely cross open prairies (Barnum 1975).

Western gray squirrels do not appear to be abundant on Fort Lewis. Our best estimate of the number of individual squirrels seen during surveys was 38 (in surveys of 74 % of the oak habitat). This translates to 1 squirrel/13 ha of surveyed oak woodlands. We did not observe squirrels in 82% of the oak forests we surveyed. Combining our survey efforts with squirrel sightings by Fort Lewis personnel, western gray squirrels were found in 44 of 228 oak stands. The low number of occupied stands may reflect three phenomena: the distribution of oak stands over Fort Lewis, including size of stand, distance to water, and adjacency to Douglas-fir; the characteristics of individual stands as they relate to habitat quality (for example, number of mast-bearing species present); and barriers to dispersal

and colonization such as traffic. Oak/Douglas-fir stands are well-distributed across Fort Lewis, but few are known to be inhabited by western gray squirrels (Figure 2).

Habitat Characteristics

The retrospective analysis of 56 oak stands showed that squirrels were seen most often in stands > 2 ha and that were ≤ 390 m away from water. Squirrels were present in most of the large oak stands near water on Fort Lewis but were rarely seen in small (< 2 ha), isolated, and pure oak stands. Our prospective comparison of 60 oak stands showed that western gray squirrels preferred stands > 8 ha and < 600 m from water. Of the 413 oak stands on Fort Lewis, 131 were > 2 ha, and only 63 stands were > 2 ha and ≤ 390 m from water. Only 3 stands were > 8 ha and < 600 m from water. Average summer home ranges of western gray squirrels vary from 2.6 to 4.2 ha (Gilman 1986, Asserson 1974, Foster 1992). Few oak stands on Fort Lewis are > 2.6 ha and within 600 m of water. Squirrels were seen most often in stands with a mixture of conifers, oaks, and other food-bearing tree species. Specific percentages of Douglas-fir and Oregon white oak required to accommodate western gray squirrels are difficult to determine, but squirrels were rarely seen in pure oak stands isolated from Douglas-fir or in pure Douglas-fir stands away from oak. Squirrels were less likely to use stands that are tending towards pure oak; fewer squirrels were seen in stands that had > 50% Oregon white oak than in stands with a greater Douglas-fir component.

The number and variety of food-bearing trees and shrubs in a stand appeared to influence use by western gray squirrels. Bigleaf maple, Oregon ash, and indian plum appeared to be important food-bearing species. The abundance of seed and mast crops varies seasonally, annually, and among species (Nixon et al. 1975); therefore, stands with diverse food sources may provide more stable year-round food supplies for squirrels than stands with few food sources (Gurnell 1983).

High-use stands had more understory trees (which provide vertical routes for travel and escape) than low-use stands. The percent cover of shrubs was not significantly different between low and high-use, but the variety of food-producing shrubs was greater in high-use stands. High-use stands had more snowberry (*Sytnphoricarpos albus*), California hazel (*Corylus cornuta*), bigleaf maple, vine maple (*Acer circinatuni*), salal (*Gaultheria shallon*), blackberries (*Rubus* spp.), and Oregon ash than low-use stands. Use by squirrels was lower in stands where Scot's broom was most abundant. Scot's broom is a highly invasive species that may quickly take over disturbed areas, prairies, and oak woodlands. Much of the understory of oak woodlands on Fort Lewis, particularly those adjacent to prairies, has been invaded by Scot's broom. Scot's broom can grow over 3 m tall and may create shade conditions unsuitable for the establishment of oak seedlings and other native prairie vegetation. Squirrels are not known to eat the foliage, pods, or seeds of Scot's broom.

The differences in ground vegetation and coarse woody debris between high-use and low-use oak stands appear to be a function of the location of the stand in the conifer forest-oak woodland-prairie mosaic. They may indicate high soil moisture and suitability for fungal production. Low-use oak woodlands had lower basal areas of trees (less tree cover) than high-use stands (Table 2). In general, low-use stands were more open and drier while high-use stands were denser and moister. Grasses were abundant in the dry open oak stands adjacent to prairies, while ferns and mosses were abundant in the moist, denser stands. Coarse woody debris is a characteristic of older interior forests rather than open prairies. Coarse woody debris can provide moist microclimates in otherwise dry areas that allow persistence and fruiting of the sporocarps (truffles) of ectomycorrhizal fungi (Amaranthus 1989).

Behavior

Activities of squirrels appear to vary in response to the breeding season and food availability. The breeding season extends from January to September in western Washington (Brown 1985). The high level of travel in the winter and spring may correspond to the search for mates or for scarce stored food. Agonistic behavior between squirrels in the spring and early summer may be associated with mating in the early spring, and defense of home ranges against dispersing young in the summer.

Food species diversity was an important correlate of squirrel occupancy of oak stands. We

observed western gray squirrels eating a variety of foods as mentioned in the results but there have been few studies of the western gray squirrel diet in Washington. Gaulke and Gaulke (1984) studied western gray squirrels on the Oak Creek Wildlife Recreation Area near Naches, Washington and found that acorns are a major food during February and March and ponderosa pine (*Pinus ponderosa*) seeds a major food in February. They observed squirrels eating large numbers of immature aspen (*Populus tremuloides*) catkins. In California, Stienecker and Browning (1970) determined principle foods by volume: hypogeous fungi, pine nuts, acorns, bay fruit, and green vegetation. Fungi were eaten year-round while pine nuts and acorns were the main summer foods. In southern Oregon, Cross (1969) found that pine seeds, fir seeds, and hypogeous fungi were eaten year-round while acorns were eaten in fall and winter. In northcentral Oregon, squirrels ate fungi, conifer seed, acorns, honeysuckle nectar (*Lonicera coliosa*), and the foliage of miner's lettuce (*Montia perforiata*) in the spring and summer (Foster 1992). Although previous food habit studies showed that a diversity of food was consumed, they did not demonstrate differences in the variety of foods available in different quality habitats.

The diet of the western gray squirrel is dependent on the seasonal and yearly availability of acorns, conifer seed, fungi, and other foods. The amount of time squirrels spend on the ground versus trees also depends on the kinds of food that are available. For example, Foster (1992) observed most foraging on the ground. except in the fall when squirrels were gathering acorns from oak trees. We observed similar patterns in foraging. Most of the year, squirrels must leave the safety of trees to forage on the ground for food. Western gray squirrels do not discriminate against roads during on-the-ground travel and 25% of squirrels seen on roads were dead. Roads (particularly those with heavy traffic) are a threat to the continuing persistence of western gray squirrels. Many deaths on roads occurred in the spring when females were pregnant and, again. in summer when young were dispersing.

Management Implications

Management for the western gray squirrel should involve protecting both the squirrel and its habitat. The greatest threats to western gray squirrels on Fort Lewis appear to be habitat loss due to succession and invasion by Douglas-fir, the over-dispersion of oak woodlands, and automobile traffic. Raising public awareness of the presence and status of the western gray squirrel through brochures and posted road signs may reduce squirrel deaths on roads. Active management is critical in preserving dwindling oak woodlands.

Oak communities in other parts of Washington were diminished in the past by the removal of oak for firewood, agriculture, and grazing. They have been further reduced because of fire suppression (leading to succession by Douglas-fir), logging, and the clearing of trees for housing developments. Oak-conifer forest has high value for western gray squirrels because it provides a variety of food, cover, and nest sites (Gilman 1986). Oak provides travel ways (Foster 1992). food (in the form of acorns and edible truffles. Molina 1992), and escape cover. Conifers (Douglas-fir on Fort Lewis) provide year-round cover, nest sites (Cross 1969, Foster 1992), cone seed, and truffles (Luoma 1991). No other communities seem to support western gray squirrels in western Washington.

Oak-conifer forests are transitional communities that require continued management for their maintenance. Oregon white oak stands may be replaced by faster growing Douglas-fir and, then, by climax stands of grand fir (*Abies grandis*) or grand fir and Douglas-fir (Franklin and Dyrness 1988). On Fort Lewis, this succession to Douglas-fir is evident in most oak stands except for those that are isolated from conifers and that have little value for western gray squirrels. There is little evidence of succession from Douglas-fir to grand fir on Fort Lewis.

Our study showed that squirrels preferred large stands near water. Therefore, management should emphasize preserving oak stands that are > 8 ha and that are < 600m from water. Small stands near water and adjacent to coniferous forests are high-priority candidates for management to increase the area of oaks. Mature, acorn-producing oaks can be maintained by killing over-topping trees by girdling or felling. Growth of smaller oaks can be encouraged by releasing them from competition with conifers. Reducing competition with oak seedlings, Scot's broom, young Douglas-fir, and

invading grasses thus may be important both in allowing oaks to regenerate and in preserving native prairies. Management may include prescribed burning on prairie edges to control the invasion of Scot's broom and retain native plant species. Franklin and Dyrness (1988) report that fires set by native Americans (before European settlement) reduced the invasion by Douglas-fir and lessened the amount of brush in oak woodlands thus creating a park-like appearance.

Western gray squirrels on Fort Lewis used stands with native understory vegetation over those with Scot's broom understory. Because squirrels did not use isolated oak stands, were often killed by crossing roads, and would be highly vulnerable to predation when away from trees, we believe that once oak stands are being maintained, the next priority is to protect habitat corridors between oak patches to facilitate travel by squirrels. Adding water sources such as small manmade ponds or guzzlers (Schemitz 1980) to oak stands that are large and adjacent to conifer stands could significantly increase the amount of suitable squirrel habitat.

Maintaining a mix and juxtaposition of habitat conditions is necessary to maintain western gray squirrel populations. Fort Lewis is an important area for western gray squirrel management because it holds the largest publicly managed area of Oregon white oak in the Puget Sound region. The problem of diminishing oak communities is not unique to Fort Lewis. Oregon white oak woodlands have diminished throughout western Washington, Oregon, and California. Conservation of oak communities, and, thus the western gray squirrel, must involve the cooperation of county, state, and federal agencies and public land owners (Bleier et al. 11993). Fort Lewis foresters currently manage for the maintenance of prairies, wetlands, oak woodlands, and continuous cover variable-age conifer forests. All these habitat conditions are beneficial to western gray squirrels.

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