strategies for enhancing western gray squirrels on fort lewis

Cheryl Fimbel
The Nature Conservancy
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SAVING THE LAST GREAT PLACES ON EARTH

Executive summary

Western gray squirrels (*Sciurus griseus griseus*) have become increasingly rare in Washington, and are listed as 'threatened' by the Washington Department of Fish and Wildlife. Western gray squirrels in Washington are at the northern extent of their range, where they are associated with Oregon white oak (*Quercus garryana*) woodland communities. Oak woodland communities are also in decline, and are considered 'priority habitat' by the Washington Department of Fish and Wildlife.

The purpose of this document is to provide information to guide the recovery of western gray squirrels on Fort Lewis by: a) describing their important habitat requirements, b) identifying potential threats to the population, and c) providing options for management actions that ameliorate those threats and enhance habitat quality. The development and implementation of these management options constitute the next logical steps in the conservation of western gray squirrels on Fort Lewis, following on the initial success of actions to control dense stands of Scotch broom (*Cytisus scoparius*) and other woody invasives, remove invading conifers, and plant native oaks.

Oak woodland stands are distributed across the Fort Lewis landscape, but few stands appear to have been occupied by western gray squirrels in the recent past (Figure 1). Research describing the distribution and habitat of western gray squirrels on Fort Lewis revealed that oak-conifer stands used by squirrels were generally greater than 2 ha in size and less then 0.6 km from a water. High-use stands included a mix of conifers, oaks, and other hardwoods such as big leaf maple (*Acer macrophyllum*) and Oregon ash (*Fraxinus latifolia*) in the canopy. Large, healthy oaks and conifers (especially ponderosa pine [*Pinus ponderosa*]) are more likely to provide greater quantities of mast foods and more nest and den sites compared with smaller trees of the same species. Understory conditions in oak stands used by squirrels on Fort Lewis include patchy understory vegetation, consisting of native food-bearing shrubs or small trees such as Indian plum (*Oemleria cerasiformis*) and California hazelnut (*Corylus cornuta*), but devoid of Douglas-fir (*Pseudotsuga menziesii*) saplings, dense stands of snowberry (*Symphoricarpos alba*), and invasive species such as Scotch broom, blackberries (*Rubus* spp.), and non-native grasses.

Potential threats to the western gray squirrel population on Fort Lewis include (order does not imply importance): predation, disease, vehicle traffic, interspecific competition, disturbance, and habitat degradation (especially food supply). A summary of management activities that may reduce these threats includes:

1. Control Douglas-fir and invasive woody shrubs in the understory of oak-conifer stands to reduce predator cover and promote important native food-providing shrubs and small trees.
2. Favor native food trees to promote healthy squirrels to reduce the potential for parasite/disease outbreaks. Maintain large dominant conifers, and create additional snags and tree cavities to minimize competition for nest sites, thereby reducing the potential for parasite/disease transmission at nest sites used sequentially by different squirrels. In addition, control eastern gray squirrels outside of developed areas to reduce this potential parasite/disease reservoir.
3. Reduce the threat posed by vehicle traffic through a combination of public education, reduced speed zones, road signage, and natural and artificial overhead squirrel bridges on East Gate Road, the site of most western gray squirrel road kills on Fort Lewis.

4. Monitor and control the expansion of non-native eastern gray squirrel (*Sciurus carolinensis*) populations outside of residential areas on Fort Lewis to reduce the potential threat of interspecific competition.
5. Protect oak stands occupied by western gray squirrels by avoiding physical disturbance within 15 m of nest trees, and avoiding timber harvest, road building, or other noisy activities within 120 m of all nest trees from 1 March to 30 September to reduce the threat of disturbance to breeding squirrels. Create additional options for favorable training sites outside of oak-conifer woodlands (clear underbrush and thin Douglas-fir stands) to provide trainers and recruits with pleasant surroundings for their encampments and training exercises that are outside of oak-conifer stands favored by western gray squirrels.
6. Enhance and expand oak-conifer (especially ponderosa pine as conifer component) woodland stands to meet stand targets outlined in the plan. Emphasize a diversity of native hardwoods and conifers in the overstory, patchy native hardwood food trees and shrubs in the understory, and remove non-native or invasive woody shrubs and trees. Connect those stands through improvements that create habitat corridors to reduce the threat of habitat fragmentation and degradation. Construct water improvements where oak stands are > 600 m from water.

In addition to management actions, it is important to monitor the distribution and abundance of western gray squirrels in Fort Lewis oak-conifer woodlands to track relative abundance through time, evaluate squirrel responses to management activities, and identify high priority areas for protection. Currently, there does not appear to be a survey method that is ideal for monitoring the low density western gray squirrel population on Fort Lewis. The combination of habitat management for western gray squirrels that reduces the density of vegetation, (especially removing invasive shrubs), and additional field trials that experiment with survey methods such as: a) volunteer foot surveys, b) baited camera stations, and/or c) hair sampling devices, may yield the identification of a technique suitable for monitoring squirrels at Fort Lewis.

Management activities will be safest for western gray squirrels if they proceed slowly, at a scale of application that minimizes disturbance to individual squirrels, and with a strong research component to avoid negative impacts to the squirrels or their resources. Directed research can also be used to identify improvements in approaches and techniques for managing western gray squirrel habitat. Research topics include:

1. Additional investigation into the natural history and habitat use by western gray squirrels on Fort Lewis to better inform our understanding of important habitat components and management strategies for this rare species in Puget lowlands.
2. Evaluating the direct and indirect impacts of management actions on western gray squirrels and their critical resources.
3. Further investigation into survey techniques that meet the considerable challenge of detecting the presence of wary western gray squirrels occurring at low densities on Fort Lewis.
4. Investigation into the effects of potential competitors, especially eastern gray squirrels and Douglas' squirrels (*Tamiasciurus douglasii*), on western gray squirrels.

Lastly, management activities for western gray squirrels will support the training mission of the US Army on Fort Lewis by removing dense stands of shrubs that hinder troop movements across the landscape during training maneuvers. In turn, the improvement of additional training sites may help to reduce the scale of training impacts on specific woodlands by dispersing training activities over a broader area.

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1. Introduction

The western gray squirrel (*Sciurus griseus*) is associated with oak (*Quercus* spp.) woodlands from north-central Washington to southern California. Western gray squirrels were once described as one of the most abundant mammals in the Northwest (Bowles 1921), and historically ranged throughout Washington's oak-conifer forests. This species was so abundant in the Fort Lewis area in the mid-1900's that tree damage was attributed to high squirrel numbers (Washington Department of Wildlife 1993). Since that time, oak woodlands have been converted or degraded, and western gray squirrels in Washington have declined in number and distribution to three disjunct remnant populations that correspond to the range of Oregon white oak (*Quercus garryana*): 1) South Puget Sound centered on the Fort Lewis Military Reservation; 2) the Columbia River Gorge area in Klickitat and Yakima Counties; and 3) Chelan and Okanogan Counties (Washington Department of Wildlife 1993).

In 1993, the state of Washington listed the western gray squirrel as 'threatened' due to declining populations resulting from: habitat loss and conversion, fluctuating food supplies, disease, interspecific competition, road kills and illegal shooting (Washington Department of Wildlife 1993). This species is also listed as a federal 'species of concern' for the western Washington region. Oak woodlands have been accorded special status as a 'priority habitat' by the Washington Department of Fish and Wildlife, and oak-dominated community types have been designated as 'Priority 1' for conservation by the Washington Natural Heritage Program (GBA Forestry 2002).

Fort Lewis is important for the western gray squirrel in a regional context because it contains: a) the largest publicly-managed area of oak woodland communities in Puget Sound, including some of the most ecologically intact and least fragmented woodlands (GBA Forestry 2002), b) the largest natural population of ponderosa pine west of the Cascade Range (Foster 1997), and c) the only known population of western gray squirrels in western Washington (Washington Department of Wildlife 1993). The western gray squirrel population on Fort Lewis is at the northern extent of its range, and appears to have declined in recent years. A 1992/1993 study on Fort Lewis reported sightings of 81 squirrels (not a population estimate) in 44 oak stands (Ryan and Carey 1995*b*), while a similar effort in 1998/1999 recorded only six observations of western gray squirrels (Bayrakci et al. 2001). This species appears to be persisting at low population numbers on the military reservation, as occasional sightings continue to be reported to the Fort Lewis Wildlife Department each year.

Wood and Koprowski (2003) suggest that even small populations of tree squirrels may be capable of recovery under favorable conditions. They used computer modeling to estimate minimum viable population (MVP) sizes for a variety of Sciurid species, although *Sciurus griseus* was not among them. Their estimates generated for several species suggest that MVP values ranged from 15 individuals under conditions of low variability in breeding success, to 195 individuals under conditions of high variability. Western gray squirrels are not the most prolific breeders among Sciurids, and therefore probably require population numbers at the higher end, or perhaps exceeding, this range. Nevertheless, this new research suggests that the small population of western gray squirrels on Fort Lewis may have potential as a viable population and merits conservation attention.

The purpose of this document is to guide the recovery of western gray squirrels (*Sciurus griseus griseus*) on Fort Lewis by: a) describing their important habitat requirements (sections 2 and 3), b) identifying potential threats to the population (section 4), and c) providing options for management actions that ameliorate those threats and enhance habitat quality (section 5). A variety of techniques for monitoring the wary squirrel population are also reviewed (section 6), along with topics for complementary research (section 7). This plan constitutes the next logical step in the conservation of western gray squirrels on Fort Lewis, following on the success of initial steps to control dense stands of Scotch broom (*Cytisus scoparius*) and other woody invasives, remove invading conifers, and plant native oaks.

2. Natural History

Aspects of the natural history of the western gray squirrel are reviewed below to gain an understanding of its important habitat components, and the ecological context of this species in its habitat.

2.1 Taxonomy

The western gray squirrel is a member of the family Sciuridae, within the order Rodentia, and includes three subspecies. The subspecies that inhabits Washington is *Sciurus griseus griseus*. The western gray squirrel was scientifically named in 1818 based on a description by Lewis and Clark of a squirrel at the Dalles, Wasco County, Oregon (Maser 1998). Despite the similarities in name and appearance, the western and eastern gray squirrels (*Sciurus carolinensis*) differ in their taxonomic relations. The western gray squirrel shares the subgenus *Hesperosciurus* with the Abert's squirrel (*Sciurus aberti*) of the southwestern United States, while the eastern gray squirrel is in the subgenus *Neosciurus* with the fox squirrel (*Sciurus niger*) of the eastern United States.

2.2 Physical Description

The western gray squirrel is also called the 'silver gray squirrel' because of its distinguishing light silver pelage. The dorsal surface is bright steel gray and appears frosted due to white-tipped hairs, while the contrasting ventral surface is creamy white. The western gray squirrel is the largest native tree squirrel in the Pacific Northwest, reaching a total length of 50 – 61 cm (Linders 2000). Foster (1992) reported that male body length was slightly longer than female body length, although Ryan and Carey (1995*a*) found no apparent sexual dimorphism in their small sample at Fort Lewis. The western gray squirrel has large ears, which are light reddish- brown on the back, and a long bushy tail that accounts for nearly half of its total length. The combination of large size, light silver pelage, large ears, and a long bushy tail help to distinguish the western gray squirrel from the non-native eastern gray squirrel at Fort Lewis.

2.3 Behavior

Western gray squirrels in the northwest are generally wary and secretive. Upon detection, they typically hide by stretching out on a limb with their tails over their backs and remain motionless. Western gray squirrels are generally arboreal, although most foraging occurs on the ground (Washington Department of Wildlife 1993). Tree nests are used by western gray squirrels for rearing young, protection from weather, day resting, and night resting.

Western gray squirrels are active throughout the day, with peak activity observed between dawn and 1100 hours (Ryan and Carey 1995*a*). Alternating periods of rest and activity occur throughout the day, with western gray squirrels returning to nests before dusk (Ryan and Carey 1995*a*). This species is primarily diurnal (Ryan and Carey 1995*a*, Linders 2000), although an individual was photographed at a water source on the ground at night in Klickitat County (Gene Orth, pers. comm.).

Western gray squirrels are active throughout the year, but are most visible in August and September when they are collecting and scatterhoarding acorns (Ryan and Carey 1995*b*). They also are typically silent, except for August through October, when they may vocalize with an occasional, hoarse warning bark – "chuff, chuff, chuff" (Maser 1998). Western gray squirrels are least visible in June and July (Ryan and Carey 1995*a*).

Western gray squirrel activity patterns are influenced by weather conditions, food availability, disturbance, and competition (Ryan and Carey 1995*a*). They are reported to be less active during extremes in weather such as high heat and stormy weather (summarized in Ryan and Carey 1995*a* and Linders 2000). Primary activities recorded for western gray squirrels on Fort Lewis by Ryan and Carey (1995*b*) varied by season (Table 1), although foraging (including burying, and eating food items) was the most common out-of-nest activity observed overall. In spring and summer, squirrels were more likely to be observed on the ground, whereas in fall and winter, they were as likely to be observed in trees as on the ground.

*Table 1. Activity category and corresponding primary observation periods for western gray squirrels at Fort Lewis, Washington, 1992-1993 (summary of information in Ryan and Carey 1995*b*).*

Activity Category	**Primary Observation Periods**
Travel	*November through March*, squirrels spent most of their time traveling on the ground and searching for buried acorns. Travel decreased in late spring and early summer, then increased again in late fall.
Agonistic behavior	*April, May and June*, squirrels spent much of their time engaged in agonistic behavior with other western gray squirrels.
Sexual behavior	*May,* squirrel sexual behavior was observed only in this month.
Foraging	*July through October*, out-of-nest time mostly devoted to foraging.

2.4 Reproduction

Male and female western gray squirrels reach sexual maturity the first winter after their birth (Ryan and Carey 1995*a*). Behavior during the breeding season involves much chasing by both males and females. Reproductive activities occur from January through September in western Washington (Ryan and Carey 1995*a*). In Oregon, females were observed in estrus in two main peaks: 1) January through March, and 2) June (Foster 1992). Female western gray squirrels in Klickitat County entered natal dens from February through July, with the main peak in April and a smaller peak in June (Aker 2003). Lactating females were observed in two peaks in Oregon: March and April, and again in July through October (Foster 1992). It appears that there are two main breeding seasons, although researchers report that females produce a single litter per year (Foster 1992). The second peak in estrus and breeding may provide a second opportunity if early spring reproduction is unsuccessful. A winter food shortage could lead to a late, rather than early, spring breeding because squirrel reproduction is sensitive to food shortage (Byrne 1979).

A litter of two to five naked young is born after a gestation period of 44 days (Ingles 1965). In Klickitat County, the young spend approximately 8 – 10 weeks in a natal den, typically an oak cavity, and then they are moved to a stick nest in a conifer tree (Aker 2003). Juveniles begin emerging from the nest in May (Washington Department of Wildlife 1993). Adults are silent and unobtrusive while rearing young, perhaps to avoid attracting predators (Maser 1998).

2.5 Home Range

Western gray squirrel habitat use varies with age, season, year, food availability, habitat quality, and population density (review in Ryan and Carey 1995*a*). Estimates of home range size for individual squirrels also vary considerably according to the method of calculation. Measurements of home range size reported for western gray squirrels from Washington to California vary from 0.1 to 73 ha per individual (summarized in Linders 2000). Squirrels in Klickitat County exhibited the largest mean annual home ranges reported for this species, with 21 ha (3.5% overlap) for female western gray squirrels and 73 ha (12.6% overlap) for males (Linders 2000). Research on other western gray squirrel populations supports this pattern of smaller female home ranges with less overlap compared to male home ranges (Ryan and Carey 1995*a*).

Male home ranges overlapped several female home ranges in the Klickitat study area (Linders 2000). Male home ranges may be larger, and overlap female home ranges to accommodate a breeding strategy allowing males access to several females. In this case, the male home range size would reflect range use by several females.

Ryan and Carey (1995*a*) did not measure home range sizes of western gray squirrels on Fort Lewis, but they consistently observed 2 different groups of western gray squirrels using two different oak stands, each 0.8 – 1.2 ha in size for 2 months and 9 months. They suggest that

0.8 – 1.2 ha is a minimum size for short-term use, while long term occupancy probably requires at least 2 ha.

2.6 Diet

Throughout its range, the diet of the western gray squirrel includes acorns, seeds and nuts of trees and shrubs, hypogeous fungi (below ground truffles and false truffles, hereafter condensed to 'truffles'), epigeous fungi (above ground mushrooms), and fleshy fruits and green vegetation. Acorns and conifer seeds (Douglas-fir and ponderosa pine in Washington) are critical high energy foods for accumulating body fat in preparation for cold weather (Steinecker and Browning 1970). Pine seeds are high in lipids and moderately high in carbohydrates, while acorns are a concentrated source of carbohydrates (Steinecker and Browning 1970). In contrast to fungi, which do not store well, hard mast can be cached for winter food reserves. Western gray squirrels bury their acorns individually in holes 1.5 to 2.0 inches deep (scatter hoards), and relocate them later by smell (Ingles 1965). Western gray squirrels in Klickitat County and elsewhere in ponderosa pine habitat feed heavily on green pinecones during the summer months (Foster 1992, Linders 2000).

Although highly nutritious and good 'keepers', acorns and conifer seeds are unpredictable food sources. The availability of hard mast is highly variable from year to year, and depends on: a) weather (current and previous year), especially temperature and rainfall, b) availability of soil nutrients, influenced by previous seed crops, and c) diseases and parasites of the tree (reviewed in Ryan and Carey 1995*a*). Oregon white oaks average intervals of two to three years between acorn crops, ponderosa pines average two to five years, and Douglas-fir average two to eleven years between large seed crops (USDA 1974). The inclusion of fungi and several different types of nuts and seeds, including hazelnut, bigleaf maple, vine maple, and Oregon ash in the western gray squirrel diet may be a strategy to buffer the effects of poor acorn and conifer seed years. In summary, habitat quality increases as the number and variety of food-bearing trees and shrubs in a stand increase (Foster 1992, Ryan and Carey 1995*a*)

Truffles are principal foods of western gray squirrels in Oregon and California, and may comprise more than 50% of their annual diet (review in Ryan and Carey 1995*a* and Linders 2000). Despite the numerical importance of truffles in the diet, their nutritional value for squirrels is relatively low compared to other food items (Carey et al. 2002). Compared with most mushrooms, however, truffles have a higher food value (salts, phosphorous, and protein) and lower water content (Steinecker and Browning 1970). Carey et al. (2002) found 28 species of truffles in their Fort Lewis study area, with members of the genera *Rhizopogon, Gautieria* and *Melanogaster* being most common. Truffles are generally available year round, but are most abundant in spring, and least abundant in winter (Carey et al 2002). The mean standing crop biomass on Fort Lewis ranged from 0 to 1.8 kg/ha for different sampling periods during the year (Carey et al 2002).

Western gray squirrels are generally food opportunists, and will eat buds, leaves, stems and shoots of succulent vegetation throughout the year, especially when mast is unavailable (reviewed by Ryan and Carey 1995*a*). They also are known to strip bark from conifers to eat the underlying cambium layer (Ryan and Carey 1995*a*). Maser (1998) reports that western gray squirrels eat berries and insects, and Aker (2003) cites evidence of foraging for beetles in Klickitat County from January through March.

Ryan and Carey (1995*a*) provide information on the diet of western gray squirrels at Fort Lewis (Tables 2 and 3). Ponderosa pine seeds were not identified as an important food resource at Fort Lewis, although this item is likely eaten by western gray squirrels that have access to pines. Seeds of ponderosa pine are important seasonally in the diet of western gray squirrels in Klickitat County (Linders 2000) where there are few tree species other than Oregon white oak, ponderosa pine, and Douglas-fir. Western gray squirrels drink from permanent and ephemeral open water sources such as lakes, marshes, rivers, streams, or puddles (Ryan and Carey 1995*a*). Foster (1992) observed western gray squirrels in Oregon traveling to water on a daily basis to drink. Western gray squirrels may also gain water by consuming seasonal green vegetation and fruits, as other Sciurids sometimes do (WDNR 1996).

*Table 2. Food items eaten by western gray squirrels on Fort Lewis military reservation, Washington, 1992-1993 (Ryan and Carey 1995*a*, 1995*b*).*

	spring	**summer**	**fall**	**winter**
acorns			■	■
truffles*	■		■	
hazelnuts			■	■
mushrooms	■	■	■	
maple samaras		■		■
Douglas-fir seed			■	■
Douglas-fir stam. cones	■			
Douglas-fir cambium	■			
Indian plum berries	■	■		
succulent vegetation	■			

*Truffle eating presumed but not confirmed at Fort Lewis as many 'unknown' items eaten in spring and fall when truffles are generally abundant, and truffles known to be important component of western gray squirrel diets elsewhere (Ryan and Carey 1995*a*).

*Table 3. Seasonal availability of food items (trees and shrubs) for western gray squirrels in oak woodlands at Ft. Lewis (Ryan and Carey 1995*a*).*

Food item		Spring	Summer	Fall	Winter
big-leaf maple	*Acer macrophyllum*			Samaras	
western serviceberry	*Amelanchier alnifolia*		Fruit	Fruit	
Pacific dogwood	*Cornus nuttallii*			Fruit	
Oregon ash	*Fraxinus latifolia*			Samaras	Samaras
ponderosa pine	*Pinus ponderosa*	Strobili		Cone seed	
black cottonwood	*Populus trichocarpa*	Catkins			
bitter cherry	*Prunus emarginata*		Fruit	Fruit	
Douglas-fir	*Pseudotsuga menziesii*	Strobili		Cone seed	Cone seed
Oregon white oak	*Quercus garryana*	Catkins		Acorns	
cascara	*Rhamnus purshiana*		Berry	Berry	
Pacific yew	*Taxus brevifolia*	Catkins		Fruit seeds	
vine maple	*Acer circinatum*			Samara	
grand fir	*Abies grandis*			Cone seed	
Indian plum	*Oemleria cerasiformes*		Fruit		
California hazel	*Corylus cornuta var. californica*			Nuts	
salal	*Gaultheria shallon*		Fruit	Fruit	
evergreen blackberry	*Rubus laciniatus*		Fruit		
black hawthorn	*Crataegus douglasii*		Fruit		
rose	*Rosa* sp.		Rosehip	Rosehips	
common snowberry	*Symphoricarpos albus*	Berry	Berry	Berry	Berry
currant	*Ribes* sp.		Berry		
Himalayan blackberry	*Rubus procerus*		Fruit		
red huckleberry	*Vaccinium parvifolium*		Berry	Berry	
apple	Pyrus malus			Fruit & bark	
fungi (truffles/mush)		present	present	present	

3. Habitat Use

Western gray squirrels are associated with Oregon white oak habitat in most of their range in Washington (Ryan and Carey 1995*a*). They inhabit ponderosa pine – Oregon white oak forests in south-central Washington, and Douglas-fir-Oregon white oak woodlands in the southern Puget Trough (Washington Department of Wildlife 1993). Relict stands of ponderosa pine also occur in the southern Puget Trough and are used by western gray squirrels on Fort Lewis (Bayrakci et al. 2001). Understory vegetation of oak woodlands in the Puget Trough is dominated by Scotch broom (*Cytisus scoparius*), snowberry (*Symphoricarpos alba*), California hazel (*Corylus cornuta* var. *californica*), Indian plum (*Oemleria cerasiformes*), and swordfern (*Polystichum munitum*) (Ryan and Carey 1995*a*).

Western gray squirrels rely on fluctuating resources, and move between vegetation types in response to food availability and other daily and seasonal requirements (Washington Department of Wildlife 1993). Research on western gray squirrels on Fort Lewis revealed that squirrels were observed most often in the larger oak-conifer stands ($\geq$ 2 ha) that were close to water ($\leq$ 0.6 km) (Ryan and Carey 199b). Larger stands near water may provide greater access to a diversity of resources to sustain more than one squirrel throughout an annual cycle (Ryan and Carey 1995*a*). Water probably serves at least two functions in the habitat. Squirrels drink from open water sources, and perhaps more importantly, they use plant food resources that are associated with more mesic sites. Kettle depressions ringed by oaks and a variety of other hardwoods that grade into conifer forest are an example of a combination of elements that can provide high quality habitat for western gray squirrels in the Puget Trough.

Research has been used to identify specific elements of habitats used by western gray squirrels in Washington and elsewhere. Primary western gray squirrel research study sites considered below include the oak-conifer woodlands of the Puget Trough and the ponderosa pine – oak communities of the eastern Cascades of Washington and Oregon. Oak communities in the Puget Trough grow in a relatively mild and wet (80- 90 cm annual precipation) climate (Thysell and Carey 2001), and are often associated with water features such as ponds, kettles, lakes, or streams that are widespread in the landscape. However, well-drained soils, combined with frequent summer droughts, promote some habitat elements characteristic of drier growing conditions. In contrast, the ponderosa pine – oak community of the Klickitat study area in south-central Washington grows in a drier climate (~63 cm annual precipitation, Linders 2000) with little useable precipitation during the growing season. A review of habitat elements is provided below, and in some instances, italics are used to highlight habitat parameters that were useful in formulating specific recommendations for habitat enhancements in section 5.6.

3.1 Overstory

The combination of hardwoods and conifers in close proximity appears to be important to meet the annual needs of western gray squirrels. Oaks provide critical winter mast, natal den cavities, seasonal cover, and travel and escape routes. Conifer trees provide cone seed, truffles (Carey et al. 2002), nest sites, year round cover, travel and escape routes. Ponderosa pines may provide a high quality resource as the conifer component of western gray squirrel habitat because the pines provide larger seeds in their cones compared to Douglas-fir, and the foliage is less dense, and may not shade out oaks to the extent that Douglas-fir does (Mary Linders, pers. comm.). Western gray squirrels in Klickitat County demonstrated consistent use of large pines in all aspects of their natural ecology (Linders 2000). Large healthy oaks and conifers likely provide the highest quality habitat due to their high food (mast and mycorrhizal fungi) production, nesting, and cover values (Linders 2000), and large branches for aerial connectivity as travel lanes (Foster 1992).

Research on Fort Lewis showed that high squirrel use stands were more moist and densely stocked with trees compared to the drier and more open low-use stands (Ryan and Carey 1995*b*). At Fort Lewis, stand basal area for the sum of all tree species averaged 27 m^2/ha in high-use squirrel stands, compared with 22m^2/ha and 16.2 m^2/ha in moderate- and low-use stands, respectively, and a mean of 21m^2/ha for all stands measured (Ryan and Carey 1995*b*). Ryan and Carey (1995*a*) recommend maintaining the oak component of the stand at a minimum of 4 m2/ha.

The mean basal area of core areas of western gray squirrel home ranges in the oak-ponderosa pine forests of Klickitat County was comparable at 26.3 m^2/ha (Linders 2000). Source habitat for the closely related Abert's squirrel in Arizona measured 35 m^2/ha, with > 20 trees/ha from 45.7 – 61 cm dbh (Dodd et al. 1998 in Linders 2000). Linders (2000) suggests that western gray squirrel habitat quality may be positively correlated with stand basal area. This relationship is not well understood and is undoubtedly influenced by the canopy and understory species composition, stand structure (sizes of trees and their individual crowns), and other species of squirrel present as potential competitors. For example, mast trees probably contribute more to the habitat than non-mast trees, and fewer large trees may be preferable to many suppressed pole sized trees contributing to the basal area. *Stand basal areas in the range of 27 – 35 m^2/ha, with a minimum oak component of 4 m^2/ha, and 20+ large (40+cm dbh) trees/ha, may contribute to suitable habitat for western gray squirrels on Fort Lewis*.

Linders (2000) observed that "trees in primary (western gray squirrel) areas in Klickitat County were notably larger in height and diameter, and denser than in surrounding areas". In high-use squirrel stands at Fort Lewis, mean stem diameters for Douglas-fir and Oregon white oak were 48.5 cm and 21.5 cm, respectively (Ryan and Carey 1995*b*). These diameters were higher than those reported for Douglas-fir, Oregon white oak and ponderosa pine (31.2 cm, 17.4 cm, and 24.3 cm, respectively) in core areas of squirrels in Klickitat County (Linders 2000), perhaps due to smaller trees in general as a result of less favorable growing conditions in Klickitat compared to western Washington. *Minimum mean tree diameters of 48 cm dbh for Douglas-fir, 21 cm dbh for oak, and 24 cm dbh for ponderosa pine may contribute to suitable habitat for western gray squirrels on Fort Lewis.*

Tree density averaged 244 trees/ha in high-use squirrel stands and 217 trees/ha in moderate-use stands on Fort Lewis, although this difference was not statistically significant (Ryan and Carey 1995*b*). These are some of the lowest tree densities reported for western gray squirrel habitat. Linders (2000) recorded 583 trees/ha in the general use area, and 474 trees/ha in nest areas of the ponderosa pine – oak habitat used by squirrels in Klickitat County and also cites a range of densities from 349 – 843 trees/ha from other western gray squirrel study areas. Fewer and larger diameter trees on Fort Lewis may constitute a high quality habitat element because large dominant trees are capable of producing more mast than smaller, crowded trees. Tree densities that are favorable for western gray squirrels would be expected to be responsive to tree size. Where Fort Lewis stands support relatively large trees (dbh's equal to or larger than the species specific means reported above), 244 trees/ha may provide suitable western gray squirrel habitat. In stands supporting trees with mean diameters smaller than the above species specific means, tree densities approaching 450 trees/ha may provide higher quality habitat for squirrels (assuming other variables, such as species composition, are constant). *Tree densities ranging from 244 – 450 trees/ha (depending on mean diameters) may contribute to suitable habitat for western gray squirrels on Fort Lewis*.

Ryan and Carey (1995*a*) recommend maintaining a total canopy cover of 40-60 percent for western gray squirrels in the Puget Trough. Suitable canopy cover would be expected to vary according to community types that range from dry open form woodland trees to more dense stands of hardwoods and conifers in more mesic sites grading into wetlands or riparian zones.

Patchy distribution of the canopy cover, or variable spacing of the trees within the stand, would probably be beneficial to squirrels by providing conditions that promote the growth of large open canopies and rapid growth of select trees (Andrew Carey, pers. comm.). *Total canopy cover ranging from 40 – 60%, with variable tree spacing, may contribute to suitable habitat for western gray squirrels on Fort Lewis*.

Squirrels on Fort Lewis were observed most often in ecotonal (transitional) areas between Oregon white oak and Douglas-fir stands (Ryan and Carey 1995*a*). Pure oak stands, and isolated oak trees on the prairies were generally not used by western gray squirrels (Ryan and Carey 1995*a*, 1995*b*). Fewer squirrels were seen in stands that contained >50% oak that in stands with a greater Douglas-fir component (Ryan and Carey 1995*b*). Other hardwood trees in the canopy contribute to a diverse food resource base on Fort Lewis, especially bigleaf maple (*Acer macrohpyllum*), and Oregon ash (*Fraxinus latifolia*) (Ryan and Carey 1995*a*). High use stands on Fort Lewis contained on average: Douglas-fir - 53% of the stand BA, oak – 34 %, and other hardwoods – 13% (Ryan and Carey 1995*a*, 1995*b*). Ryan and Carey (1995*a*) recommend maintaining tree species composition at 25 – 75% Douglas-fir, 25 – 75% oak, and 10 – 20% other hardwoods for western gray squirrels in the Puget Trough.

Home ranges of western gray squirrels in the ponderosa pine –oak community of Klickitat County contained greater amounts of conifers compared with oak stands occupied by western gray squirrels on Fort Lewis. Species composition by percent of tree frequency in western gray squirrel core areas in Klickitat included 76.8% conifer (69.6% ponderosa pine + 7.2% Douglas-fir), and 23.2 % oaks (Linders 2000). The only vegetation type actually selected for by squirrels was the moderate density (25-75% canopy closure) conifer only (primarily ponderosa pine) vegetation type (Linders 2000). They also included moderate density stands of oak and mixed oak-conifer vegetation types in their home ranges in proportion to their availability (i.e. neither selected for nor against) (Linders 2000). These values highlight the importance of ponderosa pine to western gray squirrels at the Klickitat County study site, and suggest that pines may provide a high quality resource for squirrels at Fort Lewis also. *Tree species composition of the stand overstory that includes 35 – 75% conifer, 25 – 55% oak, and 10 – 20% other hardwoods may contribute to suitable habitat for western gray squirrels on Fort Lewis*.

3.2 Understory

Western gray squirrels on Fort Lewis were more often found in stands with a patchy understory compared with stands having a dense or barren understory (Ryan and Carey 1995*a*, 1995*b*). High-use stands had a higher percent cover of understory trees than low-use stands (Ryan and Carey 1995*b*). Native food bearing deciduous trees in the understory such as bigleaf maple, Oregon ash, Indian plum, and California hazelnut, enhance the quality of the site by providing a diverse food resource base.

Shrub cover on Fort Lewis oak-conifer woodlands ranged from 41.9% in high-use stands, to 50.3% in low-use stands, although the difference was not statistically significant (Ryan and Carey 1995*b*). The species composition of shrubs in these stands did differ significantly. Food-bearing shrubs contributed more to the shrub cover in high-use stands, whereas Scotch broom was more abundant in low-use stands. Scotch broom is an aggressive invasive shrub that may considerably degrade the quality of the woodland understory for western gray squirrels by obstructing visibility, providing predator cover, providing fuel ladders for fire to move into the tree canopy, and competing with native food bearing shrubs, saplings, and trees. Douglas-fir saplings and dense concentrations of snowberry, although native species, probably occur at higher densities than historical levels due to fire suppression, and also may degrade the quality of the woodland understory for western gray squirrels for the same reasons as Scotch broom. Shrub cover was much lower in the ponderosa pine-oak habitat at the Klickitat study area, with 75% of sites having sparse cover (0-10%), and an additional 21% with moderate cover (11 – 30%) (Linders 2000). Most shrubs were less than 1 m in height in the western gray squirrel habitat in Klickitat (Linders 2000). Studies of western gray squirrels in other locations report lower values for shrub cover compared with values reported for Fort Lewis (reviewed in Linders 2000).

The high shrub cover values reported for high-use stands at Fort Lewis (Ryan and Carey 1995*b*) are relatively unusual compared to other study areas. Puget Sound oak communities are smaller and occur under a reduced range of site conditions compared to pre-settlement times (Thysell and Carey 2001). The current high shrub cover is probably more prevalent throughout many of Fort Lewis's oak-conifer stands compared to historic levels due to the loss of fire as an ecosystem process and invasion by non-native species (see section 4.6). In addition, woodlands in relatively mesic sites (favored by western gray squirrels [Ryan and Carey 1995*b*]) may be more highly invaded by conifers and invasive shrubs compared to drier woodlands, due to the greater moisture availability. Finally, many of the woodlands that have relatively open understories are used for a variety of military training operations throughout the year, including vehicle maneuvers and encampments, which may deter use by squirrels. Although Ryan and Carey (1995*b*) provide an excellent quantitative characterization of stands used by western gray squirrels on Fort Lewis, these are descriptions of existing habitat, much of which has probably undergone considerable changes in the last 150 years, and therefore, may not represent ideal habitat features for squirrels. The dense concentrations of shrubs (especially non-native shrubs) and conifer saplings probably constitute relatively recent changes in the habitat, and may not be favorable for western gray squirrels. *A low (0 – 10%) cover of non-food shrubs and trees, and a moderate (30 – 50%) cover of patchily distributed native food bearing shrubs and trees in the understory may contribute to suitable habitat for western gray squirrels on Fort Lewis*.

High-use stands had more ferns and mosses at the ground layer, compared with low-use stands that contained more grasses and forbs (Ryan and Carey 1995*b*). Forbs and non-native pasture grasses that are often tall and dense, may provide more continuous ground cover than ferns and mosses, obstructing visibility for western gray squirrels and potentially providing cover for some ground predators.

3.3 Nest Sites

Western gray squirrels use both tree cavities (Figure 2) and stick nests (Figure 3). Squirrels with more than 25 nest relocations in Klickitat County used an average of 17.3 nests each (Linders 2000). Tree cavities have been used for rearing young (Linders 2000). Western gray squirrels use tree cavities created by damage or disease, or females may enlarge old woodpecker holes for natal dens (Ingles 1965). The decay characteristics of Oregon white oak are favorable for the creation of cavities for use by wildlife (Larsen and Morgan 1998). Oaks contained significantly more cavities than Douglas-fir or big-leaf maple in Oregon, and both live and dead oak trees may contain excavated cavities (Gumtow-Farrior 1991 cited in WDNR 1996).

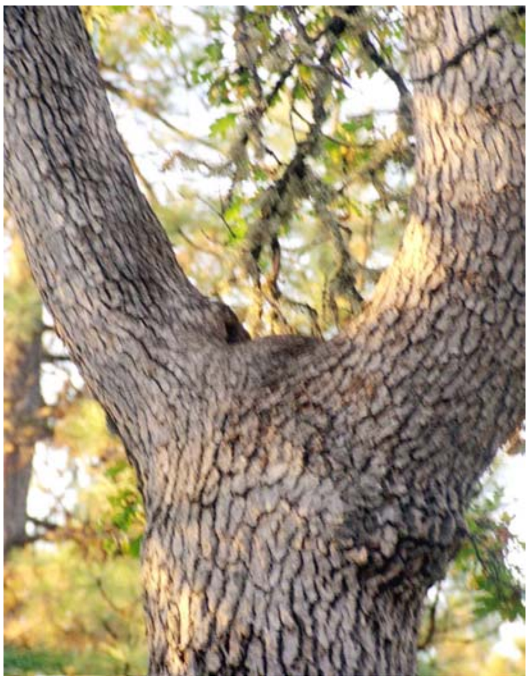

Figure 2. Cavity nest site in main fork of Oregon white oak tree used by a western gray squirrel for brood rearing on the Klickitat Wildlife Management Area, Klickitat County, Washington.

Figure 3. Platform style western gray squirrel stick nest located approximately 1/3 from the top of a ponderosa pine tree on the Klickitat Wildlife Management Area, Klickitat County, Washington.

Round platform style stick nests approximately 60 cm in diameter are normally placed in the forks of stout branches or next to the trunk, and approximately 1/3 of the distance from the top of the tree in pole to sawtimber-sized conifers (Washington Department of Wildlife 1993). The nests may be lined with lichen, moss, and bark shavings from hardwood trees (Maser 1998). A variation of the platform nest is a 'shelter' style stick nest that is constructed with a thick roof to provide more protection from inclement weather and for rearing young (Foster 1992). Linders (2000) reports that shelter nests were the predominant nest type used by western gray squirrels in Klickitat County, especially in the fall. Platform nests were used most often during the summer.

On Fort Lewis, western gray squirrel nests were observed in Douglas-fir trees, located primarily in the forks of branches (Ryan and Carey *1995a*). The use of cavity nests was not documented. An eastern gray squirrel was observed entering a cavity in an Oregon ash on Fort Lewis (pers. observ.). Stick nests most commonly were found in ponderosa pine in northeastern Oregon and Klickitat County, Washington (Foster 1992 and Linders 2000, respectively). Foster (1992) reported no use of cavity nests in Oregon, although oak cavities were used for rearing young, and very occasionally, by non-breeding adults in Klickitat County, Washington (Linders 2000).

Consistent with other reports in the literature, nest trees used by western gray squirrels in Klickitat County were larger and had more interlocking crowns (4.1) compared to trees in the surrounding matrix (2.8 – 3.0 interlocking crowns) (Linders 2000). Nest trees were primarily dominant or co-dominant ponderosa pines (Linders 2000). Mean stem diameters (dbh) of nest trees in Klickitat County were 40 cm (range = 16-78 cm, n = 79) for ponderosa pine, 46 cm (range = 25-65 cm, n = 11, cavities only) for Oregon white oak, and 48 cm (range = 19-62 cm, n= 20) for Douglas-fir (Linders 2000). In north central Oregon, Foster (1992) found that the percent canopy closure (average 60%) and proximity to water (<185 m) were the most important components of nest tree sites. *Large trees (>40cm dbh for conifers and >46 cm dbh for oaks) with a minimum of four interlocking crowns present as potential nest trees may contribute to suitable habitat for western gray squirrels on Fort Lewis*.

Finally, western gray squirrels are described as cautious in their approach to the nest, and generally enter the canopy several trees from the nest, working their way through the canopy to their nests (Foster 1992). Interconnected canopies that allow for arboreal travel at least 60 m around nest trees were important components of nest tree sites in Oregon (Foster 1992).

4. Potential Threats to Western Gray Squirrels on Fort Lewis

Limited food availability (especially mast crops such as pine seeds and acorns) can have cascading detrimental effects in a western gray squirrel population (Foster 1992). Insufficient food may lead to poor physical condition, making squirrels more susceptible to endemic parasites such as skin mites that cause hair loss and diminished thermoregulation, potentially leading to death. Poor nutrition may also influence population numbers through diminished reproductive rates (Foster 1992). Predation has been identified as a prominent mortality factor in Klickitat County (section 4.1), and road mortalities are known from Fort Lewis. The threats most likely to impact western gray squirrels on Fort Lewis are reviewed below. The order of presentation does not imply importance, as the relative ordering of threats is not known for the Fort Lewis population. It is likely, however, that one of the more important factors affecting the western gray squirrel population is availability and access to food, which may be influenced by several of the threats identified below, most notably habitat degradation in oak woodlands (section 4.6).

Direct Threats

4.1 Predation

The most likely predators capable of taking western gray squirrels in the Puget Sound region include the: red-tailed hawk (*Buteo jamaicensis*), great-horned owl (*Bubo virginianus*), bobcat (*Felis rufus*), coyote (*Canis latrans*), red fox (*Vulpes fulva*), long-tailed weasel (*Mustela* *frenata*), and domestic dogs and cats. Predation can take a high toll on western gray squirrels. Linders (2000) reports that 7 of 12 (58%) squirrels that died or were lost to her study were predated. Aker (2003) reports that juveniles and adults in Klickitat County experienced predations rates of 23% (n=34) and 49% (n=21) respectively. Many of these were attributed to coyotes or bobcats. Foster (1992) reports that a coyote devoured an entire squirrel except for some fur, while two bobcat kill sites were characterized by the remains of the tail, large intestine, gall bladder, and the radio-collar of the squirrel.

Shrubby or dense vegetation such as Scotch broom and snowberry in the understory of oak-conifer woodlands may serve as cover for some predators. At the same time, this cover may be useful to the squirrels as cover from aerial predators such as hawks or owls, or some land predators, such as the long-tailed weasel, that can hunt in open conditions. A portion of the study area in Klickitat County with denser concentrations of understory shrubs may have experienced higher levels of predation, compared with a nearby area characterized by a sparse shrub layer (Gene Orth, pers. comm, unpubl. data under review).

4.2 Disease

Notoedric mange is reported to have reached epidemic proportions and decimated various populations of western gray squirrels throughout its range (Washington Department of Wildlife 1993). Some individuals and populations recover from the disease, but small populations may not rebound from serious epidemics. Mange in squirrels is caused by a mite, *Notoedres centrifera* (*douglasi*), which burrows under the skin and causes lesions and hair loss, with the exposed skin becoming thickened. Hair loss occurs first in the chest and shoulders region and then progresses over the body. Linders (2000) observed that individuals with advanced cases of mange exhibited weight loss and lack of coordination, and were more likely to remain in an alert crouch than run when disturbed. Squirrels with mange in Klickitat County also exhibited anomalous nesting habits. They were two observations of nests at the base of trees in winter where the temperature was 10^{o} C warmer than the lower branches. Individuals with mange also used oak cavities more often than other healthy adults (Linders 2000).

An outbreak of mange was documented on the Klickitat Wildlife Area in south-central Washington in 1998 and 1999. Of 56 squirrels live trapped, 33 (59%) had mange lesions, and 14 (42%) affected squirrels died of mange or secondary complications resulting from mange, such as emaciation (Cornish et al. 2001). Factors that may have contributed to the outbreak of the disease included mast crop failure and transmission of mites among animals during live-trapping procedures (Cornish et al. 2001). Notoedric mites are not transmissible to humans, and do not pose a threat to the human population, nor are they likely to affect canids and other wild carnivores that are susceptible to the sarcoptes form of mange (Michigan Department of Natural Resources, internet web site).

Other diseases that may afflict western gray squirrels include coccidiosis and western equine encephalitis virus; and parasites include fleas, ticks, mites, intestinal roundworms, and ringworm (reviewed in Washington Department of Wildlife 1993).

4.3 Vehicle Traffic

High traffic volume and/or high vehicle speeds pose serious threats to western gray squirrels on roadways. Road mortality has been documented as a threat to populations of western gray squirrels in portions of Yakima and Klickitat Counties (Washington Department of Wildlife 1993) and on Fort Lewis (Ryan and Carey 1995*a*, 1995*b*). Road mortality has been recorded on Fort Lewis since they began maintaining records of western gray squirrels sightings in 1967. Road mortality may affect a relatively large percentage of the squirrel population where numbers are low . During a 1992 – 1993 study on Fort Lewis, 13 of 81 (16%) western gray squirrels detected by the survey were found dead on roads, with the majority (92%) occurring on one primary road (East Gate Road) that bisects a wetland corridor (Ryan and Carey 1995*a*, 1995*b*). The majority (85%) of roadkills in this study occurred between the months of April and August (peaks of gestation and dispersal), and included pregnant and lactating females, and dispersing juveniles (Ryan and Carey 1995*a*).

Indirect

4.4 Interspecific Competition

Species that may compete with the western gray squirrel for food, shelter, or nest sites (especially cavities) on Fort Lewis include the eastern gray squirrel, Douglas' squirrel *(Tamiasciurus douglasii)*, northern flying squirrel (*Glaucomys sabrinus*), Townsend chipmunk (*Tamias townsendii*), porcupine (*Erethizon dorsatum*), raccoon (*Procyon lotor*), skunk (*Mephitis mephitis*), black-tailed deer (*Odocoileus hemionus columbianus*), Steller's jay (*Cyanocitta stelleri*), scrub jay (*Aphelocoma coerulescens*), crow (*Corvus brachyrhynchos*), northern flicker (*Colaptes auratus*), American kestrel (*Falco sparvarius*) and several owl species (Washington Department of Wildlife 1993, Ryan and Carey 1995*a*). Other tree squirrels and woodpeckers are reported to be more aggressive than the western gray squirrel (Washington Department of Wildlife 1993), and are strong competitors for hard mast and nest cavities. In Klickitat County, the death of a young western gray squirrel was attributed to a Douglas' squirrel (Gene Orth, pers. comm.). Northern flying squirrels depend heavily on truffles (Carey et al 2002) and exploit this resource that is often important to western gray squirrels.

Competitive interactions between eastern and western gray squirrels are not well described. Eastern gray squirrels are ecologically more flexible than western gray squirrels, and therefore have a competitive advantage (Ryan and Carey 1995*a*). Eastern gray squirrels are capable of producing two litters per year under favorable conditions with abundant food, whereas western gray squirrels appear to be limited to a single litter per year (see section 2.4). Eastern gray squirrels can survive in natural wildlands, but unlike western gray squirrels, are also able to exploit residential and agricultural areas such as orchards, parks and suburbs, and can thrive in our increasingly urbanized habitats.

In California, Byrne (1979) reports that the introduction of non-native squirrels (eastern gray squirrels and fox squirrels), progressed without a major displacement of western gray squirrels, with the exception of a few localized supplanted populations in riparian areas. These three species exhibited some niche partitioning by sometimes occupying different vegetation types within the same general locale. The eastern gray squirrels were more successful in the moist woodlands, but did not become established in the drier uplands largely occupied by western gray squirrels (Byrne 1979). Eastern gray squirrels also were more successful in parks and residential areas where western gray squirrels were not present. Eastern gray squirrels did not include hypogeous fungi in their diets to the extent that western gray squirrels did (Byrne 1979).

In the Puget Trough of western Washington, western gray squirrels typically vacate their habitat if it is degraded by development, and then non-native eastern gray squirrels may follow the path of development into the already vacated habitat (Washington Department of Wildlife 1993). Eastern gray squirrels are generally associated with settled areas in Fort Lewis, although they have been observed and trapped at interior sites that support western gray squirrels (Ryan and Carey 1995*b*). It appears that some eastern gray squirrels are becoming established in the interior natural areas of Fort Lewis as evidenced by a road-killed lactating female in the interior, and regular observations of multiple eastern gray squirrels and leaf nests on the west side of Chambers Lake (pers. obs.).

4.5 Disturbance

Populations at the edge of a species' range often occupy marginal habitat, exhibit low numbers and sporadic distribution, and are generally more susceptible to changes in their environment (Washington Department of Wildlife 1993). Western gray squirrels in Washington are known to be sensitive to disturbance and respond to major changes in their habitat such as residential or urban development by vacating the altered habitat (Washington Department of Wildlife 1993). They may respond to minor disturbances by suspending activity for long periods (Linders 2000). Females with young are likely to be particularly sensitive to disturbance, and easily stressed, because of the added energy demands of lactation. Disturbance near nest trees may inhibit feeding, or cause a female to vacate or relocate the nest, possibly resulting in loss of young (WDNR 1996).

Disturbance levels are relatively high in Fort Lewis oak woodlands between mid-May and mid-August when an influx of thousands of ROTC recruits train and camp on the military reserve. This period is also within the reproductive season for the western gray squirrel (see section 2.4). Many oak woodland habitat patches are occupied by encampments or experience day-use by soldiers during this period. Some of the oak woodlands are attractive for training because of the shade they provide during hot days, and the relatively wide tree spacing, compared with Douglas-fir communities. Other areas of Fort Lewis are subject to more regular disturbance regimes, such as small arms fire in the Central Impact Area. Animals are more likely to habituate to disturbance events that are frequent or regular, compared to infrequent or sporadic disturbance events. Therefore, squirrel habitat in areas subject to relatively low level but frequent disturbance regimes may offer opportunities meaningful enhancements.

4.6 Habitat Degradation

Oak communities, specifically oak-conifer woodlands, define primary habitat for western gray squirrels on Fort Lewis (Ryan and Carey 1995*a*). Ponderosa pines are important to western gray squirrels in south-central Washington (Linders 2000) and Fort Lewis contains the largest natural population of ponderosa pine west of the Cascade Range (Foster 1997). It is likely that ponderosa pines contribute to high quality habitat for western gray squirrels at Fort Lewis also.

Compared to pre-settlement times, the quantity and quality of present-day oak woodlands on Fort Lewis have been considerably altered through changes in land use (GBA Forestry 2002). Historic oak woodlands and pine communities were characterized as mosaics of savannas comprised of large solitary individuals (oaks or pines) and open-canopied woodlands containing native prairie vegetation in their understory (Foster 1997). Frequent, low-intensity, and fast moving fires set mainly by Native Americans were important in maintaining the open condition of northwest woodlands (Agee 1993). The Salish people are reported to have burned the forest edges every three years to encourage berry production (Purdue 1997). Frequent burns favored native grasses and forbs in oak and pine woodlands, and reduced woody shrubs such as snowberry, and competing conifers such as Douglas-fir. Less frequent but extensive forest fires described by early settlers (Morris 1934) would have impacted these woodland communities also. An historic fire return interval of 5 – 25 years has been estimated for oak-dominated woodlands, and 10 – 50 years for oak-conifer woodlands on Fort Lewis (GBA Forestry 2002). Pines develop fire-resistant bark sooner than Douglas-firs, and were therefore favored by the frequent low-intensity fire regime (Agee 1996). Both mature oaks and pines are fire-resistant, and these communities depended on periodic low-intensity fires to eliminate competing species, especially Douglas-fir (Ryan and Carey 1995*a*, Foster 1997).

The arrival of Europeans and their gradual appropriation of land in the mid 1800's eventually led to a policy of fire suppression and subsequent invasion of oak and pine woodlands by woody shrubs and trees. Fire suppression has favored the creation of closed-canopy, Douglas-fir dominated forests with scattered large pines (Foster 1997) and/or suppressed oaks (GBA Forestry 2002) on soils that historically supported open woodlands. The dense shade in the understory suppresses pine and oak regeneration, and the original native prairie ground cover has been replaced by forest understory vegetation and invasive species (Foster 1997). Additional changes wrought by Europeans resulted in oak woodlands being lost to development and removal of oaks for firewood, while remaining oak woodlands were degraded by cattle and sheep grazing and the introduction of non-native grasses and shrubs.

Oak woodlands on Fort Lewis continue to be degraded by a combination of conifer encroachment, succession, and invasion of non-native species (GBA Forestry 2002). The understories of many oak-conifer woodlands are conducive to Douglas-fir establishment because they provide partial shade that favors moisture retention on the drought-prone Puget soils, and contain ectomycorrhizal fungi that are beneficial to Douglas-fir seedling establishment and growth (review in Ryan and Carey 1995*a*). The juxtaposition of oak woodlands next to prairies also facilitates the invasion of woodlands by Scotch broom, an aggressive invasive species that is prevalent on prairies. Oak-conifer woodlands are a transitional community and sustaining squirrel habitat presents a considerable maintenance challenge. The difficulty lies in promoting aerial connectivity and close juxtaposition of oaks and conifers, while preventing overtopping of oaks by faster growing conifers. Ponderosa pine may be superior to Douglas-fir as the conifer component of oak-conifer woodlands because its foliage is less dense, and less likely to impact the shade-intolerant oaks. Information generated from follow-up research at oak release sites on Fort Lewis (Harrington and Kern 2001) may provide additional guidance concerning shade tolerance parameters for oak growth.

5. Options for Reducing Threats to Western Gray Squirrels

Options for ameliorating previously identified threats to western gray squirrels on Fort Lewis are provided below. These options are derived from information presented previously in this report. Order of presentation does not imply priority of implementation. In the case of habitat degradation, specific habitat targets are offered to facilitate the habitat enhancement process.

5.1 Predation

Most predators on Fort Lewis are native species, and should not be controlled. Habitat enhancements that control non-native understory woody and grass invasives (leaving the native food bearing shrubs and small trees) may decrease the threat of predation to western gray squirrels by removing cover for some ground predators. At the same time, understory vegetation may provide some escape cover for squirrels, especially from aerial predators. Further research is needed to determine the relative predator pressures on western gray squirrels. In the interim, it would be prudent to control non-native and invasive vegetation to create a patchy understory and promote the relatively open historical conditions described for oak woodlands (section 4.6). Control of dense vegetation in the understory, especially Scotch broom, Douglas-fir saplings, and extensive concentrations of snowberry, requires repeat periodic interventions to remove new and regenerating plants. Feral dogs and cats are not currently known to be a problem on Fort Lewis. If their populations were to increase dramatically, their numbers could be reduced by trapping and removal.

5.2 Disease

Disease, or increased parasite loads, are often associated with dense concentrations of animals. Western gray squirrels at Fort Lewis appear to occur at low densities, and therefore disease may not be a prominent threat factor for this population. Disease does, however, have the potential to seriously affect western gray squirrels at Fort Lewis because of the isolated nature of this relatively small population. If a disease outbreak did occur, it could affect the whole population, with no opportunity for re-colonization from surrounding habitat. A disease outbreak may not be density-dependent if an environmental stress factor such as a mast crop failure contributes to poor physical condition. Habitat enhancements that promote food trees for western gray squirrels could aid in disease prevention by allowing squirrels to maintain a healthy body condition. The creation of additional snags and tree cavities (section

5.6 below) may also aid disease prevention through reduced competition for cavity nest sites, thereby reducing the opportunity for disease transmission at a nest site.

The notoedric mange mite is generally believed to be present at low levels among squirrels and may intensify due to variations in parasite or host populations (Cornish et al. 2001), or when squirrels are under stress. Human activities that disturb the squirrel population may promote conditions that cause stress and favor a disease outbreak. Thus, minimizing human disturbance near habitat occupied by western gray squirrels may help to reduce the potential for disease. A program to monitor and control eastern gray squirrel numbers in habitat outside of residential areas (see section 5.4 below) may also reduce the threat of mange by removing this potential reservoir.

The Michigan Department of Natural Resources (internet web site) reports that both sarcoptic and notoedric mange mites may be controlled by a variety of acaricidal compounds. The conventional treatment for sarcoptic mange in domestic animals consists of repeat oral dosings of a parasiticide ‘Ivermectin’, which would not be practical for treatment of wild squirrels. Selamectin (trade name ‘Revolution’) is a new topical parasiticide that is reputed to control sarcopitc mange in dogs with a single application. If squirrels with mange could be live trapped, selamectin could potentially be used to control mange on captured individuals. In collaboration with a wildlife veterinarian, the chemical should be tested on eastern gray squirrels before considering use on western gray squirrels, to test for harmful effects and effectiveness in control of notoedric mange. The wildlife veterinarian at the Washington Department of Fish and Wildlife should be contacted immediately if symptoms of mange are detected or suspected in the western or eastern gray squirrel populations on Fort Lewis.

5.3 Vehicle Traffic

The threat from vehicle traffic may be reduced through a combination of public education, reduced speed limits, road signs, and natural and artificial overhead squirrel bridges on East Gate Road, the site of the majority of documented western gray squirrel road kills on Fort Lewis. The Environmental Awareness component of Fort Lewis’ Integrated Training and Monitoring program could develop informational brochures to explain the status of the western gray squirrel and the impacts of road mortality for the purpose of increasing public awareness and concern.

Squirrel mortality on roads may be reduced by lowering the speed of vehicles on relatively high speed primary roads, and encouraging drivers to watch for crossing squirrels. To this end, it may be useful to reduce the speed limit in the section of East Gate Road where most squirrel mortality occurs. In addition, signs posted along major roads at squirrel crossing areas that warn drivers to be alert for squirrels on the road may cause drivers to exercise extra caution in those critical areas. It may also be useful to activate blinking lights on these road signs between the months of April and August, when the majority of road mortalities occur, and the squirrel population is most vulnerable due to dependant young, and dispersing juveniles.

An aerial squirrel bridge that links trees on the north and south sides of East Gate Rd. in the area where most mortalities occur may help to reduce the threat posed by vehicle traffic on this major road. A natural aerial bridge formed by branches of trees on opposing sides of the road is the best option for western gray squirrels, as they regularly use branches as travel lanes. Thus, encouraging (i.e. no cutting) natural bridges of tree branches on opposing sides of high traffic roads in squirrel habitat on Fort Lewis would promote natural aerial pathways. Where natural bridges are not likely to form, and road mortality is a occurring with some regularity, the construction of an artificial bridge or overpass may be warranted. Eastern gray squirrels regularly use a specially devised squirrel bridge in the town of Longview, Washington. It is likely that western gray squirrels are also capable of using a squirrel bridge, but their wary behavior may preclude use of such a device. Instructions for the construction of a squirrel bridge are included in Appendix A.

Avoiding enhancements for western gray squirrels in habitat located near roads with heavy traffic may help to reduce road mortalities. A buffer of at least 100 m of open or unsuitable habitat on either side of a roadway may help to keep squirrels off roadways. For example, it would probably not be desirable to convert the entire gravel pit just north of East Gate Road into a ponderosa pine savanna or oak-ponderosa pine woodland because of the high traffic volume on East Gate Road. Improved habitat close to this major road may act as a mortality sink.

5.4 Interspecific Competition

Most of the potential competitors identified previously in section 4.4 are native species, and therefore should not be controlled. The introduced eastern gray squirrel is a notable exception, and it would be prudent to monitor and control this species in habitat outside of residential areas. Trapping and removing eastern gray squirrels outside of developed areas on Fort Lewis is recommended to reduce the threat of potential competition with western gray squirrels. Eastern gray squirrels are relatively easy to capture in baited traps (Ryan and Carey 1995*a*, Bayrakci et al. 2001), and the population of eastern gray squirrels at the picnic area on the west side of Chambers Lake is a priority for removal in the near future.

Another option for reducing potential competition with eastern gray squirrels would be to avoid habitat enhancements for western gray squirrels within one kilometer of residential areas where eastern gray squirrels are probably most abundant. Habitat enhancements in western gray squirrel habitat near developed areas may serve as a stepping stone to attract eastern gray squirrels into the more traditional western gray squirrel habitat in the interior of Fort Lewis, and should therefore be avoided. Education programs that discourage feeding of eastern gray squirrels by residents may dampen the positive effects of artificial feeding on eastern gray squirrel numbers.

If western gray squirrels are using cavity nests, and nests are limited (not known at this time), habitat enhancements that create additional snags and promote cavity trees may help to reduce potential interspecific competition for nest sites in cavities. Installation of artificial nest boxes suitable for western gray squirrel use may be considered for the same reason, although the effort may not be warranted for such a low-density population. Approximately 24 nest boxes were originally installed on Douglas-fir trees in 1975, but there are no data to describe their use. A cursory effort by the author to relocate these 28 year old nest boxes was unsuccessful.

5.5 Disturbance

Western gray squirrels are rare and therefore vulnerable to disturbance on Fort Lewis, especially during their reproductive season, March through September. Avoiding physical disturbance within 15 m of nest trees, and avoiding timber harvest, road building, or other noisy activities within 120 m of all nest trees from 1 March to 30 September may help to reduce the threat of disturbance to breeding females (WDNR 1996).

As the distribution of western gray squirrels becomes better known through a monitoring program, occupied oak stands could be protected as no-entry zones for recreation-oriented or non-essential human activities. This would be especially true during their most vulnerable time, the reproductive season (March through September). To minimize the disturbance to squirrels and their habitat posed by military training activities (especially the spring and summer ROTC activities in oak-conifer woodlands), it may be useful to create more options for favorable training conditions outside of oak-conifer woodlands. This may include clearing underbrush and some thinning activities in Douglas-fir forest to allow trainers and recruits pleasant surroundings for their encampments, which include relatively easy walking conditions and a shaded environment for the hot summer temperatures. Eventually, Range Control could encourage trainers to take advantage of these cleared Douglas-fir sites, while avoiding oak-conifer stands occupied by western gray squirrels.

To minimize disturbance to western gray squirrels from habitat enhancements designed to help them, management activities should be applied at small scales. Ideally, mechanized equipment or large-scale disturbances would not occur in habitat occupied or used frequently by western gray squirrels. In cases where occupied or frequently used stands would benefit from enhancements, a conservative approach would be to undertake enhancements in nearby stands, and then eventually conduct small scale or minimal enhancements in the frequent use stand when the squirrels have access to nearby improved refuge habitat.

Application of enhancement actions that cause drastic changes in the habit applied at large scales could be detrimental to squirrels or their resources. For example, enhancement actions that entirely clear the underbrush, remove large numbers of trees, or include the use of prescribed fire, should not be applied to large contiguous sections of habitat occupied by squirrels in a single treatment. The direct and indirect effects of the proposed enhancement actions on western gray squirrels have not been investigated. Potential unintended direct consequences include squirrels vacating the site due to repeat human disturbance, and the potential for fire or smoke to kill young if conducted at the wrong time of the year. Potential unintended indirect consequences include loss of food or nest resources, and shifts in competitive relationships that favor other species. Enhancement activities that proceed slowly and with strong monitoring and research components are most likely to have positive effects while avoiding negative impacts to squirrels.

Disturbance to the *vegetation* of the oak-conifer woodland habitat is also of concern, and can be minimized by limiting trails and roads that accelerate root damage to oaks (oak roots are near the surface and are sensitive to compaction and digging) and invasions by weedy species. Heavy construction equipment or trucks and tracked vehicles may be particularly damaging to oak roots, oak regeneration (saplings), and possibly fungal production.

5.6 Habitat Degradation

The threat to western gray squirrels posed by habitat degradation may be reduced by enhancing and expanding oak-conifer woodland stands and linking these stands through improvements to habitat corridors. Reducing the threat of habitat degradation requires strategies at both the landscape and stand levels. Considerable attention has been devoted to the topic of restoration of Oregon white oak habitats in Washington (Hann and Dunn 1996 and Larsen and Morgan 1998), and a management strategy was recently elaborated for oak woodland communities on Fort Lewis (GBA Forestry 2002). These documents provide good direction for restoring oak woodlands, and thus strategies and options provided below should be considered supplemental to the documents mentioned above, as recommendations below are specific to managing components of oak-conifer communities as habitat for western gray squirrels.

Landscape Level
A landscape level strategy could include enhancement of oak-conifer woodlands, initially targeting: 1) the larger oak-conifer woodlands containing ponderosa pine, and near water features but removed from human settlement, and 2) oak-conifer woodlands adjacent to stands currently occupied by western gray squirrels. At the same time, it would be useful to identify and improve habitat corridors, especially forested stands that follow stream courses or riparian zones.

Where conifer forest exists between oak-conifer woodlands, portions of the conifer forest could be enhanced as corridors by promoting oak-conifer stand targets identified below, including: stand basal area, canopy cover, species composition, understory food trees and control of invasive shrubs in the understory. A conservative approach would be to target oak or hardwood stands within the conifer forest matrix of the corridor, and enhance those oak stands to serve as stepping stones, eventually targeting enhancements in the connecting conifer forest.

Where open habitat exists, corridors may be created to link oak-conifer stands by planting stands of trees that approach the oak-conifer stand targets described below. This constitutes a long-term option, as the trees would not be suitable as corridor habitat for several decades. Furthermore, medium and high quality native prairie habitat should not be converted to habitat corridors for western gray squirrels as prairie habitats are of conservation concern also.

Stand Level
Stand level reversal of habitat degradation could include enhancing and expanding existing oak-conifer woodland stands to approach a ‘desired condition’ derived from research on

western gray squirrels. A description of a desired stand condition for western gray squirrels on Fort Lewis is summarized from sections 2 and 3 and includes:

> An oak-conifer stand with a minimum size of 2 ha, containing large live, open-form oaks with a second age class to replace aging oaks, inter-digitating with a multi-layered conifer stand (mix of ponderosa pine and Douglas-fir as the conifer component) and associated deciduous trees. Stands used by squirrels include large trees with aerial connectivity and a patchy understory consisting of a variety of native food trees and shrubs and prairie plants, and devoid of dense stands of Scotch broom, young Douglas-fir, blackberry shrubs, and snowberry (although a native species, in the absence of fire, snowberry concentrations today are probably more continuous and dense compared to historical conditions). The presence of a water source such as a lake, pond, stream, marsh, or spring within 600 m of the stand is also important.

Specific targets are outlined below to bring conditions in oak-conifer stands closer to this desired condition. These targets are based on information presented previously in sections 3.1 – 3.3 and recommendations in Ryan and Carey (1995*a*) and WDNR (1996). Despite the specificity of the targets, their impacts on the squirrels and their habitat cannot be wholly anticipated. Therefore, implementation of management actions toward these targets should be conducted with prudence, a strong research component, and at a scale that is not likely to be harmful to individual western gray squirrels. An additional principal guideline for implementing targets at any given site includes consideration of: a) the probable historical (pre-settlement) condition and natural disturbance regime, along with b) the site's potential based on local edaphic conditions. Finally, variability and patchiness in the distribution of both the overstory and understory trees and shrubs within the stand will promote a heterogenous mosaic of habitat elements (dense concentrations and large open canopy forms) in close juxtaposition, which will offer a range of habitat conditions of potential benefit to western gray squirrels.

Following on the identification of stands for habitat enhancements, stands could be managed for the following structural and compositional target characteristics. To promote adaptive management, information gained through complementary research (section 7) could be used to refine and improve these targets and approaches through time.

1. Target: Minimum stand size 2 ha initially, eventually increase minimum stand size to 4 ha.
   Plant additional oaks or other hardwoods (especially big leaf maple and Oregon ash), and ponderosa pines to extend existing oak-conifer stand size as conditions allow. This would be especially applicable where oak-conifer woodlands are adjacent to open habitat, but not medium or high quality native prairies, which are also of conservation concern. Also a priority would be the expansion of oak stands around kettle depressions as they generally contain a variety of native hardwood trees and shrubs (Thysell and Carey 2001).

2. Target: Stands $\leq$ 600 m from water.
   This target is easily met for many of the oak-conifer woodlands. Where high quality oak-conifer woodland stands are greater than 600 m from a water source, consider creating a man-made pond or adding an artificial water improvement such as a 'guzzler' (Schemitz 1980) that was installed on the Klickitat Wildlife Area in Klickitat County.

3. Target: Stand basal area 27 – 35 m^2/ha, with oak component $\geq$ 4 m^2/ha.
   Thin or plant trees to attain this target, with attention to tree density, diameter and species composition in targets below.
   For planning purposes, approximate potential diameter growth rates are as follow:
      Oregon white oak = 1.25 cm/decade (Stein 1990)
      Ponderosa pine = 12 cm/decade (Oliver and Ryker 1990)

4. Target: Minimum mean tree diameters 48.5 cm dbh for Douglas-fir, 21.5 cm dbh for oak and 24 cm dbh for ponderosa pine.
   Promote old growth oaks and conifers (see Figure 4) and larger trees of all species, yet retaining some smaller trees for future stand replacement.

5. Target: Tree density 245 – 450 trees/ha.
   Where trees are relatively large (greater than mean dbh for Douglas-fir = 48.5 and oak = 21.5 cm [Ryan and Carey 1995*b*]), 244 trees/ha may be suitable for western gray squirrel habitat. In stands supporting trees with mean diameters smaller than those identified in the preceding sentence, it may be beneficial to promote larger trees, while in the interim, supporting a higher tree density up to 450 trees/ha. Promote variable spacing of trees within a stand to favor development of large form trees or rapid growth of select trees.

6. Target: Minimum of 20 conifers > 40 cm dbh per ha of oak-conifer woodland, and one oak > 46 cm dbh per 10 ha of oak-conifer woodland, as potential nest trees with a mean of 4 interlocking crowns per nest tree.
   Promote growth or retention of several interior large conifers, and the largest oaks, as potential nest trees with well connected canopies for at least 60 m in several directions from each potential nest tree.

7. Target: Stand canopy cover at 40% – 60%
   Retain at least 50% canopy coverage within 120 m of potential nest trees (large, dominant conifers) to promote aerial connectivity among tree crowns and facilitate arboreal travel between nest trees and important resources such as water or foraging habitat.

8. Target: Tree species composition of stand overstory to approximate (as % of total):
   35% - 75% conifer (ponderosa pine is preferred species for this component, and higher percent conifer [i.e. 65%-75%] especially where pine is predominant species). Information generated by monitoring the response of 'released' oaks by Harrington and Kern (2001) may help to define shade limits for oak growth, and may allow for a refinement of values provided here.
   25% - 55% Oregon white oak
   10% - 20% other hardwoods (see Table 4).

9. Target: 30% - 50% cover of native food shrubs and/or small trees in the understory.
   Promote and/or plant native food bearing shrubs or small trees in the understory or at the edge of an oak-conifer stand as appropriate for site conditions (Table 4).

10. Target: 0 - 10% cover of non-food shrubs in the understory
    Clear the understory of Scotch broom, young Douglas-fir, non-native blackberry, and some *dense* stands of snowberry to reduce competition for native food-bearing shrubs and small trees, and remove fuel ladders for fire.

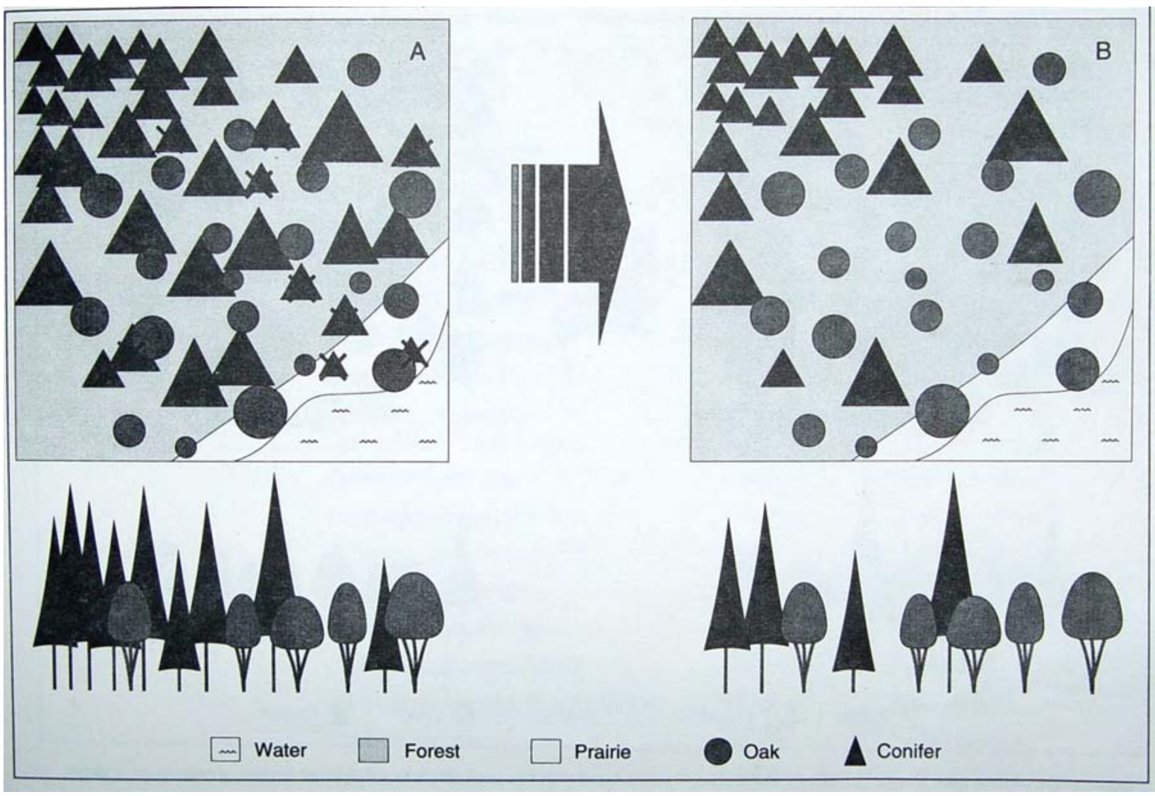

*Figure 4. Diagram reproduced from Ryan and Carey (1995*a*) showing overhead and cross-section view of a degraded Oregon white oak stand with Douglas-fir overtopping oaks (A) and same stand with selective Douglas –fir removal (B).*

Table 4. Native food bearing trees and shrubs for mixed species planting and their site conditions as described in Pojar and Mackinnon (1994), and Chappell and Crawford (1997).

Tree	Site Conditions
bigleaf maple *(Acer macrophyllum)*	• Dry to moist sites, often on sites disturbed by fire, clearing or logging.
Oregon ash *(Fraxinus latifolia)*	• Oregon white oak-Doug-fir/snowberry/swordfern community – rather closed canopy dominated by oak. • Moist to wet soils, often near streams, or areas w/ occasional flooding
Indian plum *(Oemleria cerasiformis)*	• Oregon white oak/snowberry/long-stolon sedge community – semi-open to closed canopy dominated by Oregon white oak. Douglas-fir is usually present in small amounts, but may occasionally co-dominate. • Oregon white oak-Doug-fir/snowberry/swordfern community – rather closed canopy dominated by Oregon white oak. • Oregon white oak/snowberry/moist forb community – closed canopy riparian community dominated by Oregon white oak, and occasionally co-dominated by Oregon ash. • Dry to moist open areas and woods, streambanks
California hazelnut *(Corylus cornuta)*	• Oregon white oak-Doug-fir/snowberry/swordfern community – rather closed canopy dominated by oak. • Oregon white oak/snowberry/moist forb community – closed canopy dominated by Oregon white oak, and occasionally co-dominated by Oregon ash. • Moist but well drained sites in open forest, shady openings, clearings, rocky slopes, and well-drained streamside habitats.
bitter cherry *(Prunus emarginata)*	• Moist forest and along streams, and a pioneer on logged areas
vine maple (*Acer circinatum*)	• Moist to wet places, generally under other trees where some light reaches the forest floor, such as canopy openings and forest edges.

Other habitat management considerations synthesized from the literature (primarily: Ryan and Carey 1995*b*, WDNR 1996) include:

<u>Promote large, healthy oaks</u>

- Thin dense pure oak and oak-conifer stands to reduce crowding and achieve the stand conditions described above.
- Control Douglas-fir that overtop oaks to allow oaks to grow to an open form (do not remove large individual Douglas-fir that may also be important habitat elements).
- Overtopping Douglas-fir may be girdled to provide snags, felled to provide timber, or felled and left on the ground to provide coarse woody debris to promote natural woodland characteristics.

- Promote regeneration of oaks and other hardwoods to assure stand replacement.

Protect squirrel nests, nest trees, and vicinity.
- Protect all large, live and dead oaks, and snags, as potential den trees.
- During timber harvesting operations, examine trees for the presence of nests before marking for removal.
- Identify western gray squirrel nest trees with a permanent marking system known to all field personnel,.
- Maintain a no-cut buffer within 15 m of each nest tree, unless cutting would be beneficial for squirrel habitat.
- Maintain an interconnected canopy that allows for arboreal travel routes for at least 60 m around potential nest trees (large, dominant conifers – interconnected canopy not documented as important for oak den sites, Matt Vander Haegen, pers. comm.).
- Avoid timber harvesting, road building, or other noisy activities within 120 m of all nest trees during the western gray squirrel breeding season (1 March – 30 September).

Promote aerial connectivity among important habitat components
- Maintain arboreal pathways between important components of western gray squirrel habitat such as nest trees, water sources, oak stands, and ponderosa pine stands.
- Promote a $\geq$10 m buffer of trees around permanent water sources within 600 m of western gray squirrel habitat to facilitate access to water.

Fire as a Management Tool

Prescribed fire appears to be beneficial for tree squirrels in Arizona (Pasch 2003), and is likely to improve habitat for western gray squirrels on Fort Lewis due to the historical importance of fire in the region. Prescribed fire is currently employed on Fort Lewis to restore components of the historic condition of oak woodlands and ponderosa pine communities (Foster 1997, Tveten and Fonda 1999). Periodic controlled burns employed as an enhancement tool may stimulate young oak shoot growth and reduce cover of woody invasives. However, stand conditions and fuel loads have increased considerably since the late 1800's, creating hazardous conditions for prescribed fires (Tveten and Fonda 1999). Current conditions include dense clusters of small oaks, small Douglas-firs and Scotch broom in the understory which lead to high intensity fires and provide fuel ladders, making fire potentially damaging to mature oaks and pines. Prescribed fire in woodlands with ladder fuels has the added danger of damaging or killing valuable wildlife and timber trees in a large forest fire, including large ponderosa pine and Douglas-fir trees (Regan 2001), and extending beyond the boundaries of Fort Lewis's wildlands. Removing high fuel loads and fuel ladders before conducting prescribed burns in oak-conifer woodlands may reduce the potential for damage to mature trees that are valuable to squirrels.

Non-native species have also altered the competition dynamics in oak woodlands, and the post-fire successional pathways may be markedly different from the expected trajectory. The investigation of characteristics of small scale, carefully controlled, prescribed burns to meet the stand targets described above for improving squirrel habitat constitutes a suitable topic for further research (section 7).

6. Population Monitoring

It is important to monitor the distribution and abundance of western gray squirrels in Fort Lewis oak-conifer woodlands to track changes in the relative abundance of this rare species through time and evaluate their response to habitat management actions. Knowledge of the distribution of western gray squirrels also allows managers to identify high priority areas for protection or special management actions. It would also be useful to monitor the distribution and abundance of eastern gray squirrels on Fort Lewis to inform management decisions concerning this potential competitor.

Western gray squirrels are extremely shy and wary, making their detection difficult. On Fort Lewis, western gray squirrels are most likely to be encountered in large oak-conifer stands located near water sources (Ryan and Carey 1995*a*, 1995*b*) that include stand characteristics described under the 'desired condition' (section 5.6). Survey efforts that target these stands may be most efficacious in detecting squirrels. Squirrel survey techniques are reviewed below.

6.1 Foot Surveys

Foot surveys are a common method of surveying squirrel populations. Foot surveys are used to detect the presence of squirrels by walking slowly and quietly at the edge and/or interior of a stand, stopping every 15m to look and listen for squirrels. If they are conducted systematically, foot surveys can be useful for monitoring relative abundance as a measure of individuals detected per unit effort (typically hours). A 1992-1993 investigation on Fort Lewis yielded one squirrel per 9 hours of foot survey time, compared with one squirrel per 117 hours of survey time in 1998, and no squirrels in 155 hours of survey time in 1999 (Bayrakci et al. 2001). It appears that foot surveys could be an effective technique for tracking changes in abundance of western gray squirrels at Fort Lewis, although they are relatively costly due to the considerable labor requirements.

Surveys for squirrels are most likely to be productive during peaks of squirrel activity. Western gray squirrels are most active on Fort Lewis during the months of August and September (Ryan and Carey 1995*b*). On a daily basis, they are most active in the early morning from 30 minutes after dawn to approximately 11 am (Ryan and Carey 1995*b*). Foot surveys are very labor intensive, and it would be useful to incorporate volunteer crews of knowledgeable people to reduce labor costs. The potential difficulties associated with volunteers is that they may not be able to distinguish western vs. eastern gray squirrels, and they may not be sensitive to the potential for disturbing this vulnerable population. Volunteers would need to be carefully screened and trained in identification traits and proper field methods to avoid disturbing the target animals.

6.2 Nest Surveys

Surveys of nest condition and abundance could be used to detect recent squirrel activity, but would not be useful for estimating western gray squirrel abundance. On Fort Lewis, western gray squirrels, Douglas' squirrels, and northern flying squirrels use similar nests (Ryan and

Carey 1995*a*). Accipiter nests may also resemble squirrel nests. Eastern gray squirrels have been observed using oak leaf nests in oak trees on Fort Lewis (pers. observ.), but this species may also use stick nests in conifers.

Gene Orth (pers. comm.) suggests that western gray squirrel nests in Klickitat County are characterized by woven patterns of larger boughs, which distinguishes them from Douglas' squirrel nests which are generally looser jumbles or piles of smaller twigs and needles. Several large, western gray squirrel sized (~ 60cm diameter) nests within 100 – 150 m of each other supports western gray squirrel use, whereas a single nest could signify construction by an accipiter (Anonymous 2002). Small squirrel nests (~25cm diameter) found in a cluster, but all in Douglas-fir trees, combined with the presence of fir cone middens, suggests Douglas' squirrel may have originally built the nests (Anonymous 2002).

Calibrating nest abundance to western gray squirrel abundance is further complicated by the lack of regular nest building habits. Squirrels regularly re-use nests (8.2 uses/ nest observed by Linders 2000), confounding a direct relationship between the number of nests and number of squirrels. Linders (2000) reports an average of 17.3 nests per squirrel, but indicates that the number of nests increases with the number of telemetry relocations (i.e. level of search effort or length of radiotelemetry study). Furthermore, stick nests typically accommodate one western gray squirrel at a time, although there are observations of two squirrels occupying the same nest (Linders 2000). Squirrels also may use more than one nest during a 24 hour period, as they may use one nest for day resting, and another at night.

Nests may provide some assistance in population monitoring. Western gray squirrels add vegetation to existing nests, and the presence of fresh nest material (green vegetation) could indicate recent western gray squirrel activity. Information available at this time suggests that it would be difficult to distinguish western gray squirrel nests from nests made by other resident squirrels. The topic of nest construction and use by the different Sciurids would benefit from additional research.

6.3 Calling Surveys

Hand-held squirrel calling devices were tested as a method to attract and survey squirrels in Fort Lewis woodlands (Bayrakci et al. 2001). The calls imitated eastern gray squirrel and fox squirrel distress and alarm calls. No squirrels were observed during 35 hours of calling surveys in 35 stands during the months of May and June, 1999 (Bayrakci et al. 2001). These results suggest that the calling devices used may not be efficacious for detecting western gray squirrels at Fort Lewis. Additional testing of calling devices might include playbacks of western gray squirrel 'chuffing' vocalizations during the months of August through October, which is the time of year that western gray squirrels are known to vocalize. Calling surveys, if undertaken, could be conducted as a modified form of foot surveys.

6.4 Live Trapping

Live traps are useful for capturing animals in mark-recapture studies to estimate animal densities. They are also useful for capturing animals for the purpose of attaching radio collars and studying habitat use. Wire-mesh Tomahawk live traps were baited with walnuts and peanut butter mixtures for two weeks during the months of February and March, 1999 in 22 sites known for historic observations of western gray squirrels on Fort Lewis (Bayrakci et al. 2001). A total of 8,002 trap nights were logged with no captures of western gray squirrels, 9 adult eastern gray squirrel captures, 12 Douglas' squirrels, and 25 northern flying squirrels.

In Klickitat County, western gray squirrels are readily captured in wire mesh Tomahawk live traps placed at the base of trees with an absence of understory vegetation (Figure 5). Traps are baited with walnuts in the shell, and western gray squirrels entered traps after six days of pre-baiting (open and baited traps) in Klickitat County (Mary Linders, pers. comm.).

Live trapping is labor intensive, and has not been proven to be an effective survey technique for western gray squirrels on Fort Lewis. The success of live-trapping western gray squirrels in south-central Washington (Barnum 1975, Linders 2000) and Oregon (Foster 1992) suggests there may be potential for use of live traps (although perhaps not for monitoring purposes) for western gray squirrels on Fort Lewis. Western gray squirrels may spend less time on the ground in the dense understory vegetation of Fort Lewis compared to squirrels occupying habitat with a relatively open understory. If dense understory vegetation such as Scotch broom, snowberry, and blackberries are reduced or removed from otherwise high quality habitat, western gray squirrels (if present) may alter their habits, and be more inclined to enter traps. Habitat enhancements that improve conditions in the understory of high quality stands may create conditions that are more conducive to capturing squirrels in wire mesh live traps on the ground. If further efforts are directed at encouraging squirrels to enter wire mesh traps in enhanced stands, it may be necessary to conduct one or more months of pre-baiting (monitor pre-baited traps to determine when to set traps) and target winter months when food resources are scarce, or the months of August and September when squirrels are very active gathering and scatterhoarding hard mast in caches on the ground (Ryan and Carey 1995*b*). Caution is advised when live trapping squirrels, as there is a potential for mortality associated with the trapping and handling process.

Figure 5. Example of a trap site for western gray squirrels showing wire mesh live trap baited with walnuts in the shell at the base of a ponderosa pine tree in the open understory of the the Klickitat Wildlife Management Area, Klickitat County, Washington.

6.5 Camera Surveys

Motion sensitive cameras were established at walnut bait stations in Fort Lewis oak, Douglas-fir, and ponderosa pine communities to survey western gray squirrels from May through June, 1999 (Bayrakci et al. 2001). Cameras were set for 140 camera days, and 164 photographs were obtained of animals at bait stations, including one western gray squirrel and eight eastern gray squirrels (Bayrakci et al. 2001). Camera surveys are relatively costly in terms of the initial equipment purchase, but have relatively low labor costs. The use of cameras at arboreal bait stations or nest sites is one of the more promising methods for detecting the presence of western gray squirrels because it does not require that they enter a trap or other device. Baited camera stations could be used to identify stands to target for follow-up foot surveys, or for trap and removal of eastern gray squirrels.

6.6 Track Plates

Rodrick (1986) used sooted track plates (0.5m x 0.5m) to record tracks and detect the presence of western gray squirrels in forested stands in Washington. Carey and Witt (1991) determined that track plates do not provide a reliable index of abundance for arboreal rodents. Tuna cat food in oil, shelled walnuts, and peanut butter baits, have been successful at attracting gray squirrels (Rodrick 1986). Whole walnuts are used to attract western gray squirrels to live traps in Klickitat County, and this bait may be the safest to use for squirrels because it is probably the least likely to attract predators. Track plates are relatively cumbersome and labor intensive to employ, but offer the advantage of safety for the target animals, and do not require that animals enter a trap or box (although incorporating a box with track plates would increase the resolution of the track prints, and hence the value of this technique [Zielenski and Kucera 1995]). Track plates are also limited to rain-free conditions which precludes their use for much of the year in the Puget Sound region. Other recommendations include substituting plexiglass for the aluminum plates and 'lamp black' for the carbon sooting process (Elizabeth Rodrick, pers. comm.). Baited camera stations would be easier to employ, and are therefore preferable if funds permit.

6.7 Hair Sampling

The collection of hair samples has been used as a survey technique to detect the presence of a variety of carnivores (Belant 2003) and squirrels (Gurnell et al. 2003). Hair samples may be identified to species using macroscopic or microscopic keys, or DNA analysis. If enough hairs are collected separately from individual squirrels, it may be possible to distinguish individuals, aiding in the estimation of relative abundance. Baited hair sampling devices are being considered by the Washington Department of Fish and Wildlife as a technique for detecting the presence of western gray squirrels in Washington. Gurnell et al. (2003) provide a description of a hair snaring device used for detecting the presence of squirrels in the United Kingdom:

> The collection of squirrel hairs in tubes is a simple and inexpensive way of identifying the presence of red or grey squirrels in an area. The tubes are 300 mm long and made out of 65 mm diameter round, or 65 mm x 65 mm square ended, PVC drain pipe. They should be strapped to branches at a convenient height and baited by placing sunflower seed and maize

> inside them. Two wooden or opaque plastic blocks (2.5 x 2.5 x 0.5 cm) are covered by double sided sticky tape (e.g. Scotch 'pressure sensitive' tape; Stock reference no: 465; North British Tapes Ltd; Killingworth, Tyne & Wear) and placed on the inside roof at either end of each tube, approximately 3 cm in from the entrance. Sticky blocks are retrieved and numbered after 14 days. As the animals enter the tubes to get the food, they leave some of their hairs on the tapes which are removed for later examination under a microscope. The sticky blocks should be protected at collection to prevent the hairs being damaged. Tube variations include blocking the tubes at one end, or using food hoppers with a tunnel entrance. The hairs contained on the blocks can be identified using a reference collection of red and grey squirrel hair and by staining a sample of hairs with ink if this is required.

This hair collecting tube is advantageous because it is inexpensive and requires little labor. In addition, the location of tubes in trees may facilitate their use by squirrels, compared to live traps located on the ground. The primary drawback is that it requires animals to enter a tube to remove the hairs for sampling. The wary behavior of western gray squirrels may preclude their use of the tubes. A hair collecting technique would be most useful if a method could be found that does not require the target animal to enter a trap or tube. Despite the uncertainty, this monitoring method warrants further investigation because of its low cost and relatively low labor input.

6.8 Monitoring Summary

At this time there does not appear to be a survey method that is ideal for monitoring the low density western gray squirrel population on Fort Lewis. Individual animals that occur at very low densities may become extremely wary and cautious as adaptations for survival, making their detection extremely difficult regardless of the technique. The combination of habitat enhancements and additional field trials that experiment with the survey methods described above, may yield techniques that are suitable for detecting the presence, and perhaps relative abundance, of western gray squirrels. Field trials of different techniques should be coordinated with Washington Department of Fish and Wildlife biologists who are planning further investigation of survey techniques. The combination of volunteer foot surveys directed in time and space, baited camera stations, and hair collecting devices probably offer the greatest potential at Fort Lewis.

7. Research

It is important to implement a program of research in conjunction with the management recommendations (section 5) to investigate several topics that could lead to improvements in habitat management for western gray squirrels. Scientists at the Washington Department of Fish and Wildlife and the USDA Forest Service Pacific Northwest Research Station have extensive experience with squirrel survey techniques and ecological studies, and any investigations concerning western gray squirrels on Fort Lewis would undoubtedly benefit from collaboration with these scientists. Recommended topics are addressed below.

1. Additional investigation into the natural history and habitat use by western gray squirrels on Fort Lewis would be useful to provide information for improving the identification of

important habitat components for this species, and aid in our understanding of the relative importance of potential limiting factors. Topics for further investigation could include a detailed analysis of diet by season through more than one annual cycle to understand the squirrel's diet under different environmental conditions. A detailed analysis of home range use, juvenile dispersal patterns, and predation pressures, would better inform management actions and habitat enhancements, and guide the designation of protected critical habitat. Behavior and use of overstory and understory habitat elements, and an additional understanding of requirements specific to the reproductive cycle (mating and rearing young) on Fort Lewis could better inform habitat enhancement efforts.

2. Knowing the response of western gray squirrels and their food resources to management actions is essential to evaluating the efficacy of, and making improvements to, management options proposed in this plan. Relatively major management actions such as prescribed fire, canopy thinning, and extensive underbrush clearing should be accompanied by research programs to investigate the direct and indirect effects of these actions on western gray squirrels, their critical resources (especially growth and food production), and other squirrels as potential competitors. Scientists at the USDA Forest Service Pacific Northwest Research Station are currently engaged in research programs to explore the impacts of canopy thinning and fire on Oregon white oaks at Fort Lewis (Harrington and Kern 2001, Peter and Harrington 2002, respectively). Further investigations that involve these topics would surely benefit from collaboration with these scientists.

3. Further investigation into survey techniques suitable for detecting the presence of western gray squirrels on Fort Lewis is critical for a monitoring program that tracks changes in the distribution and abundance of this rare species. Techniques that warrant further investigation include the use of volunteers to conduct foot surveys (possibly incorporating a calling device specific to western gray squirrels), baited camera stations, and a hair sampling device.

4. Investigation into the potential effects of interspecific competition with other sciurids could better inform management strategies designed to improve conditions for western gray squirrels. One approach could include investigations into the natural history and ecology of the introduced eastern gray squirrel and the native Douglas' squirrel, along with concomitant evaluations of spatial dynamics by the different species.

Personal Communications

Andrew Carey, Pacific Northwest Research Station, U.S. Forest Service, Olympia, WA

Mary Linders, Washington Department of Fish and Wildlife, Olympia, WA.

Gene Orth, Washington Department of Fish and Wildlife, Klickitat Wildlife Management Area, Klickitat County, WA.

Elizabeth Rodrick, Washington Department of Fish and Wildlife, Olympia, WA.

Matt Vander Haegen, Washington Department of Fish and Wildlife, Olympia, WA.

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APPENDIX A – SQUIRREL BRIDGE CONSTRUCTION

Squirrel Bridge Spanning Roadway in Longview

Details of Construction, written by Amos J. Peters, General Contractor. 1964

I used two 3/8" steel cables threaded through a 4" fire hose and bolted it with ¼" gal. bolts every few feet to keep the cables separated and to the outside of the hose. I then made a 10' section to put in the center of the bridge to give the appearance of a superstructure. This also supports the sign 'Nutty Narrows Bridge".

This 10' section was made from aluminum tubing, part of which had been an old TV antenna. The horizontal part was made from ¾" tubing and the bottom was made from 1 ¼" tubing bought especially for the bridge. I then bolted and welded all the parts of the superstructure together.

At the park, I measured the distance between the two trees from which the bridge would be supported, at a height of 20'. I then bolted the superstructure to the previously prepared hose and cable so that it would be in the center of the street when it was erected.

Back at the shop, I then tied one end of the cable to a truck and the other end to my crane and stretched it a distance of 60' to see how much sag it would have in it when placed between the trees. It had a tendency to turn and twist rather than stay level. This was due to the difference in tension on each of the 3/8' steel cables in the hose. We adjusted the tension until it hung just the way we wanted it to.

I then added a safety precaution by stringing a ¼" aluminum wire and attaching it to either end of the crossbar on the superstructure and extending the full length of the hose, this wire was later anchored at either end onto the supporting trees.

We had set anchors on the two trees that were to be used for supports and we were now ready to complete the bridge. We draped the entire bridge over a scaffold on the back of a truck and took it to the park. We used our crane to pick up one end of the hose and lifted it into position against the one tree.

We had constructed the anchors so that all we had to do was drop a pin in to secure the hose in position. We then picked up the other end and prepared to do the same thing on the opposite tree. We had to use a come-along in order to stretch the hose and cable into the proper position.

We also connected the aluminum support wire, previously mentioned, onto the trees at either end, and our bridge was ready for traffic. (See following page for pictures of the bridge.)

1A

1B

1C

Figure 1A Bridge spanning roadway; 1B close up of attachment at tree; and 1C view of underside of bridge.

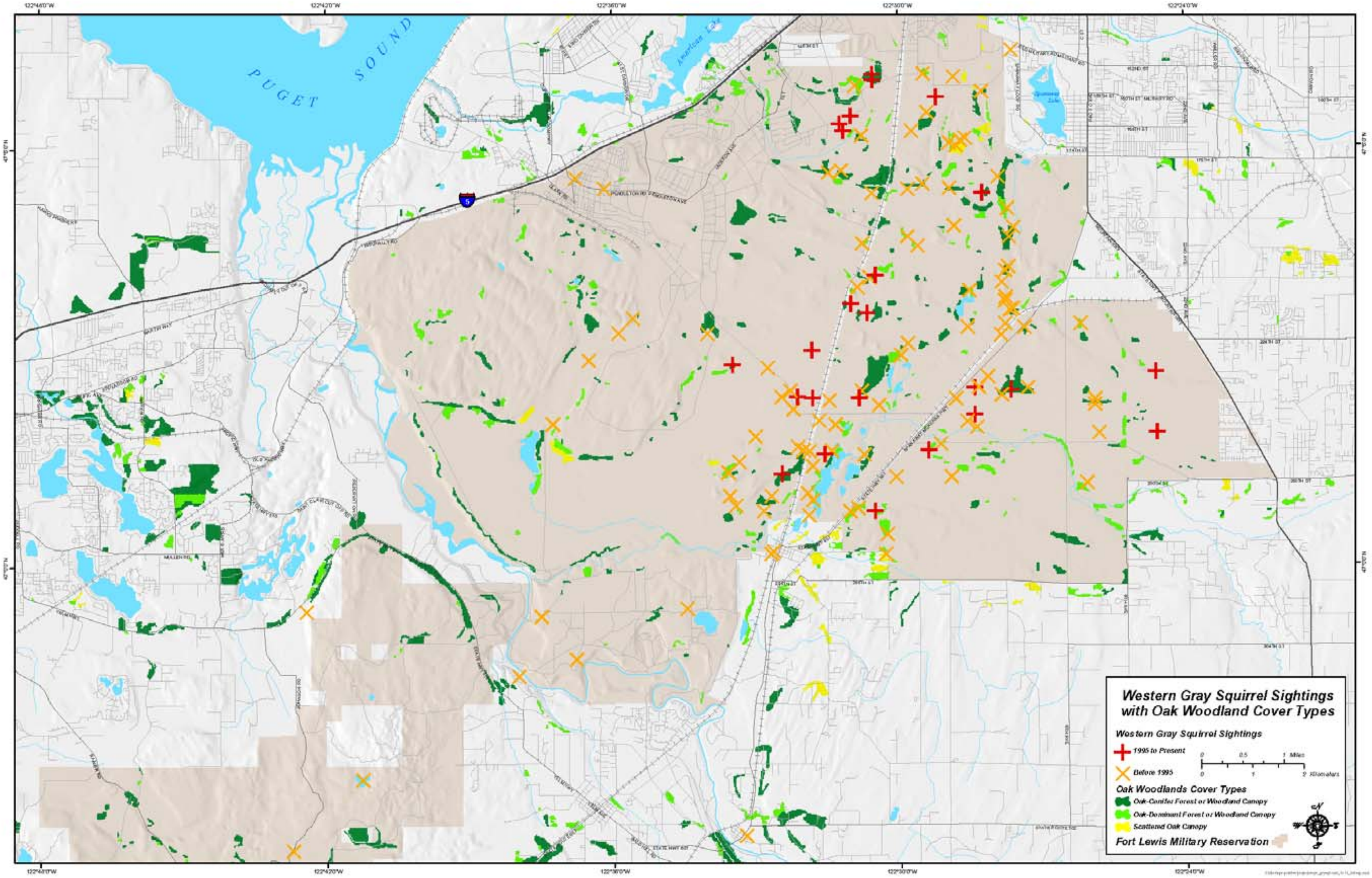

Figure 1. Locations of oak woodlands and western gray squirrel sightings on Ft Lewis, WA.