STATE OF WASHINGTON November 2007

Western Gray Squirrel Recovery Plan

by Mary J. Linders and Derek W. Stinson

Washington Department of
FISH AND WILDLIFE
Wildlife Program

In 1990, the Washington Wildlife Commission adopted procedures for listing and de-listing species as endangered, threatened, or sensitive and for writing recovery and management plans for listed species (WAC 232-12-297, Appendix E). The procedures, developed by a group of citizens, interest groups, and state and federal agencies, require preparation of recovery plans for species listed as threatened or endangered.

Recovery, as defined by the U.S. Fish and Wildlife Service, is the process by which the decline of an endangered or threatened species is arrested or reversed, and threats to its survival are neutralized, so that its long-term survival in nature can be ensured.

This is the final Washington State Recovery Plan for the Western Gray Squirrel. It summarizes the historic and current distribution and abundance of western gray squirrels in Washington and describes factors affecting the population and its habitat. It prescribes strategies to recover the species, such as protecting the population and existing habitat, evaluating and restoring habitat, potential reintroduction of western gray squirrels into vacant habitat, and initiating research and cooperative programs. Interim target population objectives and other criteria for reclassification are identified.

The draft state recovery plan for the western gray squirrel was reviewed by researchers and representatives from state, county, local, tribal, and federal agencies, and regional experts. This review was followed by a 90-day public comment period. Responses to many of the public comments are included in Appendix G. All comments received were considered in preparation of the final recovery plan. For additional information about western gray squirrels or other state listed species, check our web site (http://wdfw.wa.gov/wildlife.htm), or contact:

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This report should be cited as:

Linders, M. J., and D. W. Stinson 2007. Washington State Recovery Plan for the Western Gray Squirrel. Washington Department of Fish and Wildlife, Olympia. 128+ viii pp.

Cover photos by Rod Gilbert (squirrel) and Carl Dugger (background).
Cover and title page illustration by Darrell Pruett

WASHINGTON STATE RECOVERY PLAN FOR THE WESTERN GRAY SQUIRREL

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Wildlife Program
600 Capitol Way N
Olympia, Washington

November 2007

Approved: 11/9/07

Director, Washington Department of Fish and Wildlife   Date

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ACKNOWLEDGEMENTS

Comments received from Harriet Allen, Dave Clouse, Jim Lynch, Todd Zuchowski, John Koprowski, Gary Roloff, Todd Wilson, Joe Buchanan, Matt Vander Haegen, Sue Van Leuven, David Anderson, Carl Dugger, Bill Weiler, Lynda Hofmann, Sanders Freed, Cheryl Fimble, Sara Gregory, and Elizabeth Rodrick improved the draft. At the special request of Klickitat County, counties were provided an opportunity to review the draft before public release. County personnel and consultants, including Domoni Glass, Dave Guenther, Jim Keany, Ryan Nielson, Bryan Manly, and Wallace Erickson provided comments; their suggestions helped to improve and clarify the recovery plan. Sara Gregory and Matt Vander Haegen provided unpublished data from their research. Tom Owens, Jennifer Bohannon, Brian Consentino, Raj Deol, John Jacobson, and Shelly Snyder contributed tabular and spatial data to construct map figures, which play an important role in the plan. The Yakama Nation, North Cascades National Park, and the US Forest Service, Pacific Northwest Research Station, contributed important location data, with special assistance from Gina King, Bob Kuntz, and Todd Wilson, respectively. Darrell Pruett created the western gray squirrel illustration and adapted some figures from existing work. Many individuals, too numerous to mention, provided comments during the public comment period that improved the plan. We would like to acknowledge the efforts of many landowners and citizens who have helped conserve western gray squirrels in Washington by protecting habitat values, cooperating with surveys and research, and contributing observations.

EXECUTIVE SUMMARY

The western gray squirrel is a native arboreal squirrel best known for its large size, gray pelage, and plumose, white-tipped tail. Western gray squirrels are often confused with introduced eastern gray squirrels that are increasingly common in Washington's urban areas. Historically, western gray squirrels in Washington were widely distributed in transitional forests of mast-producing Oregon white oak, ponderosa pine, and Douglas-fir. Western gray squirrels play an important role in maintaining oak woodlands by planting acorns and disseminating spores of mycorrhizal fungi that aid tree growth.

During the 20th century the Washington population of western gray squirrels experienced great reductions in both numbers and distribution. The species now occurs as separate populations in the Puget Trough, Klickitat, and Okanogan regions that are estimated to total between 468 and 1,405 individuals. These three populations are genetically isolated from one another, and have been isolated from those in Oregon and California for at least 12,000 years. None of the three current populations seem to be large enough to avoid a decline in genetic diversity and at least two may suffer from the negative effects of inbreeding.

The western gray squirrel was listed as a threatened species in Washington in 1993 by the Washington Fish and Wildlife Commission, and its native oak habitat is recognized as a Washington Department of Fish and Wildlife Priority Habitat. The U.S. Fish and Wildlife Service considers the western gray squirrel a "species of concern" in western Washington, and the U.S. Forest Service recognizes it as a "sensitive" species and a "management indicator species" for oak-pine communities. Washington populations of the western gray squirrel have not recovered from past reductions in their range and existing populations face significant threats to their survival. The western gray squirrel is vulnerable because of the small size and isolation of remnant populations. Major threats to the western gray squirrel in Washington include habitat loss and degradation, road-kill mortality, and disease. Populations of eastern gray squirrels, fox squirrels, California ground squirrels and wild turkeys are expanding and may compete with, and negatively impact western gray squirrel populations. Competition with eastern gray squirrels may be an important current issue for the Puget Trough population and in southwestern Klickitat County, while fox squirrels may affect western gray squirrels in portions of the Okanogan region. California ground squirrels, which became established in Washington in the 20th century, may compete with western gray squirrels in Klickitat and Yakima counties.

Habitat has been lost to urbanization and other development, particularly in the south Puget Sound area, and to catastrophic wild fires in Yakima County and the Okanogan. Conifer dominated stands of large diameter and mast-producing trees of pine and oak with interconnected crowns are particularly important in the life history of the western gray squirrel. Logging that removes the large mast-producing trees and results in evenly spaced trees with few or no canopy connections reduces habitat quality. Habitat also has been degraded by fire exclusion and historic over-grazing. In the south Puget Sound area oak woodland is being degraded by the invasion of Scot's broom. Road-kill is a frequent source of mortality for western gray squirrels and is known to be a major source of mortality for the Puget Trough population. Notoedric mange, a disease caused by mites, periodically becomes epidemic in western gray squirrel populations and appears to be the predominant source of mortality in some years. The incidence and severity of mange epidemics appears to be related to stresses in the local population precipitated by periodic food shortages.

Recovery actions are needed to maintain and restore western gray squirrel populations in Washington. The recovery plan identifies western gray squirrel recovery areas and interim recovery objectives for these areas. The recovery plan outlines strategies intended to restore a viable western gray squirrel population

in the South Cascade Recovery Area and increase and maintain populations in the Puget Trough and North Cascades recovery areas. The western gray squirrel will be reclassified from State Threatened to State Sensitive status when management plans, agreements, regulations, and other mechanisms are in place that effectively protect the habitat values for western gray squirrel populations, and the following population levels are maintained:

- a total population of 3,300 adult western gray squirrels in the South Cascades Recovery Area;
- a total population of 1,000 adult western gray squirrels in the North Cascades Recovery Area;
- and a population of >300 adults is restored and maintained in the Puget Trough Recovery Area.

Recovery objectives may be modified as more is learned about the habitat needs and population structure of this species. Increasing and maintaining a population in the Puget Trough and the North Cascades may require augmentation with individuals from healthier populations. Western gray squirrel recovery strategies include protecting and monitoring populations, restoring depleted populations and degraded habitat, and protecting suitable oak-conifer habitat from harmful timber practices, catastrophic fires, and loss to development. Research is needed on the habitat requirements and factors limiting western gray squirrel populations, the role of disease in dynamics of populations, and to refine survey and population monitoring methods. Successful recovery of the western gray squirrel in Washington will depend on cooperative efforts of large and small private landowners, Native American tribes, counties, and multiple public agencies.

PART ONE: BACKGROUND

INTRODUCTION

The western gray squirrel (*Sciurus griseus* Ord) is a large native tree squirrel found in mixed oak-conifer forests in Washington, Oregon and California. It has declined in Washington where it is now restricted to three isolated populations, and one, the Puget Trough population, is near local extinction. The population decline was probably the result of habitat degradation and historical over-hunting combined with sporadic outbreaks of disease, particularly mange.

The western gray squirrel was listed as threatened by the state of Washington in 1993 (WAC 232.12.011). Recovery of western gray squirrel populations in Washington will require cooperative efforts to improve habitat protection, restore habitat, reduce human-related mortalities, reintroduce or augment depleted populations, and address non-native competitors.

TAXONOMY

The western gray squirrel belongs to the mammalian Order Rodentia, the suborder Sciuromorpha (Carraway and Verts 1994), and the family Sciuridae, which includes chipmunks, ground squirrels, prairie dogs, and marmots (Nelson 1899, Hall 1981, McLaughlin 1984). It is the only member of the subgenus *Hesperosciurus* (Hall 1981), and was first described by G. Ord in 1818 from a specimen taken by Lewis and Clark at The Dalles in Wasco County, Oregon (Thwaites 1904). Other historical Latin names assigned to the western gray squirrel include *S. leporinus* Audubon and Bachman (1841), *S. fossor* Peale (1848), and *S. heermanni* Le Conte (1852). The Latin genus name *Sciurus* means 'shade tail' referring to the habit of squirrels using their bushy tails for protection from sun or rain (Steele and Koprowski 2001). Other common names for the western gray squirrel include the gray squirrel, silver gray squirrel, California gray squirrel, Oregon gray squirrel, and Columbian gray squirrel.

Of the three western gray squirrel subspecies, the most widespread is *Sciurus griseus griseus* Ord. (Fig. 1), which occurs from Washington to central California. *S. g. nigripes* occurs along the central California coast, and *S. g. anthonyi* occurs in southern California. Western gray squirrels occurring in Baja California, Mexico (Mellink and Contreras 1993) are presumably *S. g. anthonyi*, but no work on this subject has been done.

Wade and Gilbert (1940) studied relationships among North American tree squirrels using the baculum, or penis bone, as a distinguishing characteristic. They found that the western gray squirrel shares a close phylogenetic relationship only with the Abert's squirrel, *S. aberti*, of the southwestern United States. There are many similarities between the habitat, nest trees, and food habits of Abert's and western gray squirrels (Keith 1965, Patton 1984, Dodd et al. 1998, 2003).

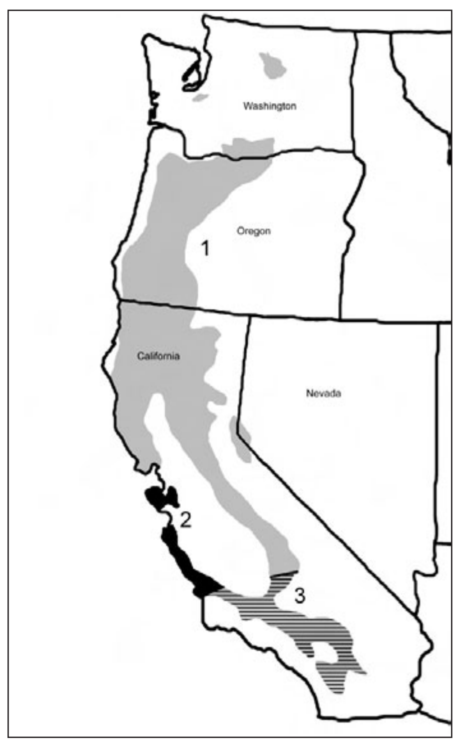


Figure 1. Current range of *S. griseus*: 1) *S. g. griseus*, 2) *S. g. nigripes*, 3) *S. g. anthony*i, (modified from Bayrakçi 1999).

DESCRIPTION

The western gray squirrel is the largest native tree squirrel in the western coastal United States (Carraway and Verts 1994). Based on data from four studies (Table 1), squirrels are significantly large in Klickitat County, Washington (Linders 2000), than elsewhere in the species range; Gilman (1986), working in California, reported the highest average body mass.

Western gray squirrels exhibit a form of coloration known as countershading. The dorsal pelage is silvery gray and the underparts are pure white. The voluminous white-tipped tail is as long as the body (Grinnell and Storer 1924, Bailey 1936, Flyger and Gates 1982). Western gray squirrels have large ears, which are reddish-brown at the back in winter and are never tufted (Bailey 1936). The body pelage remains the same through all seasons, although a yellowish wash may appear on the belly during winter (M. Linders, pers. obs.). Tree squirrels undergo a complete head-to-tail molt in the spring, and a rump-to-head molt in the fall. Tail hair is replaced only in the spring (Gurnell 1987).

Male and female western gray squirrels are not sexually dimorphic in size or color. Juveniles can be distinguished from adults by their smaller size [500 g (17.5 oz)], a wiry pelage that appears to lack guard hairs, and flattened hair on the underside of the tail (Hall 1980, Gilman 1986).

Similar species. The eastern gray (*S. carolinensis*), eastern fox (*S. niger*), and California ground (*Spermophilus beecheyi*) squirrels, are superficially similar in appearance to western gray squirrels (Plate 1). Adult eastern gray squirrels are approximately 20% smaller than western gray squirrels. The pale gray dorsal pelage has a brown to reddish wash down the back and tail, and on the face; the belly is white. The ears and tail are relatively short compared with western gray squirrels. Adult fox squirrels are similar in size to western gray squirrels, but may get slightly larger. Their dorsal pelage is rusty gray and the belly is rufous, but can be cinnamon to white in color; the ears are short. The California ground squirrel (generally <500 mm total length) has upperparts gray-brown, with light flecks and a darker triangle behind the neck. Its tail, though long for a ground squirrel, is not as large and full as those of tree squirrels (Verts and Carraway 1998).

Table 1. Western gray squirrel measurements from Washington and California. Mean ± SE (range).

Measurement	Washington				California			
	Ryan and Carey (1995a) n = 6		Linders (2000) n = 41		Crase (1973) n = 38		Gilman (1986) n = 10	
Total length (mm)	566 ± 8	(541-589)	597 ± 3	(557-633)	560 ± 4	(530-615)	568 ± 7	(520-600)
Head & body (mm)	268 ± 9	(226-287)	312 ± 2	(285-342)	286 ± 3	(255-323)	295 ± 5	(265-325)
Tail (mm)	299 ± 6	(277-315)	284 ± 1	(263-302)	274 ± 2	(248-309)	273 ± 5	(250-290)
Foot (mm)	78 ± 1	(76-79)	78 ± 0	(74-85)	76 ± 1	(61-83)	77 ± 1	(75-85)
Ear (mm)	41 ± 1	(38-43)	38 ± 0	(36-41)	35 ± 0	(31-39)	29 ± 1	(25-35)
Neck circum. (mm)	NA	NA	122 ± 1	(107-140)	NA	NA	140 ± 2	(127-147)
Weight (g)	774 ± 23	(703-833)	842 ± 12	(710-1080)	749 ± 17	(520-942)	895 ± 14	(810-930)

GEOGRAPHICAL DISTRIBUTION

North America

Western gray squirrels range from north central Washington to the southern border of California, west to the coast in California, and east to the Nevada border at Truckee (Fig. 1). Western gray squirrels have also been reported from Laguna Hanson in the central part of Sierra de Juarez, Baja California, Mexico (Mellink and Contreras 1993). The distribution of the species is poorly understood in Mexico and forest cover is discontinuous between Baja California, Mexico and southern California. They

Plate 1. Top row: western gray squirrels (left: Rod Gilbert; right: Susan Foster); Middle row: eastern gray squirrels (left: Mary Linders; right: Matt Vander Haegen); Bottom left: eastern fox squirrel (Albert Bekker, California Academy of Sciences); Bottom right: California ground squirrel (Rod Gilbert).

primarily occupy the Upper Sonoran and Transition life zones, but extend locally into the Lower Sonoran and Canadian life zones (Grinnell and Storer 1924, Bailey 1936, Ingles 1947). Little is known about the distribution of western gray squirrels prior to Euro-American settlement.

Washington

A historical range map for western gray squirrels was constructed based on historical squirrel records, vegetation zones described by Cassidy (1997), and the maps of Booth (1947) and Dalquest (1948). The Ponderosa pine, oak, Willamette Valley, Cowlitz River, and Woodland/Prairie Mosaic zones were combined and the resulting polygon was clipped at the outer extent of known historical squirrel distribution (e.g. ponderosa pine habitat on the eastside occurs all the way to Idaho) (Fig. 2).

Dalquest (1948) suggested that western gray squirrels expanded into Washington following the retreat of the Vashon Glacier 11,000–14,000 years ago. Recent genetics work in Washington suggests the western gray squirrel has been resident for at least that long (Warheit 2003). Historically, western gray squirrels were found in the Columbia River gorge and both sides of the Cascades in portions of the Transition Life Zone in Washington (Dalquest 1948, Ingles 1965; Fig. 2). They were reportedly found at low to middle elevations on the east slope of the Cascade Mountains from Klickitat County to Lake Chelan (Couch 1928, Taylor and Shaw 1929). Early museum records of western gray squirrels in Chelan County include a specimen collected near Manson in 1918, and near Lakeside in 1921. Manson is on the north shore of Lake Chelan, so western gray squirrels were likely found in adjacent areas of Okanogan County. Okanogan County opened a season on gray squirrels in 1928 (Washington Division of Game and Game Fish 1928). However, seasons on gray and black squirrels were also open in Clallam and Jefferson counties 1929–1934 (Appendix B), though there is no other evidence that these counties ever had populations of western gray squirrels (Svihla and Svihla 1933, Scheffer 1995:51). There have been anecdotal rumors that western gray squirrels were introduced in the Okanogan; these likely stem from an introduction of eastern fox squirrels in the 1940s. Bowles (1921) mentioned a similar introduction theory about the Puget Trough population and stated, "It has been a resident here ever since 1896, to my personal knowledge, and there is little doubt that they were here long before that date…It is common theory that they were introduced here, but it is much more probable that they have always been here in limited numbers." Scheffer (1923) thought that the belief that they were introduced resulted from the squirrel's rapid increase due to protection on Fort Lewis and the Tacoma game sanctuary.

Taylor and Shaw (1929) stated that western gray squirrels were found from the Columbia River to Tacoma in western Washington, and Dalquest's (1948) range map shows them along the Columbia River and in a wide band through western Skamania, Clark, Cowlitz, and Lewis Counties. However, their presence in these southwestern counties was likely assumed based on habitat, or on anecdotal reports lost to history, because there are no historical specimens or published records for southwest Wash-

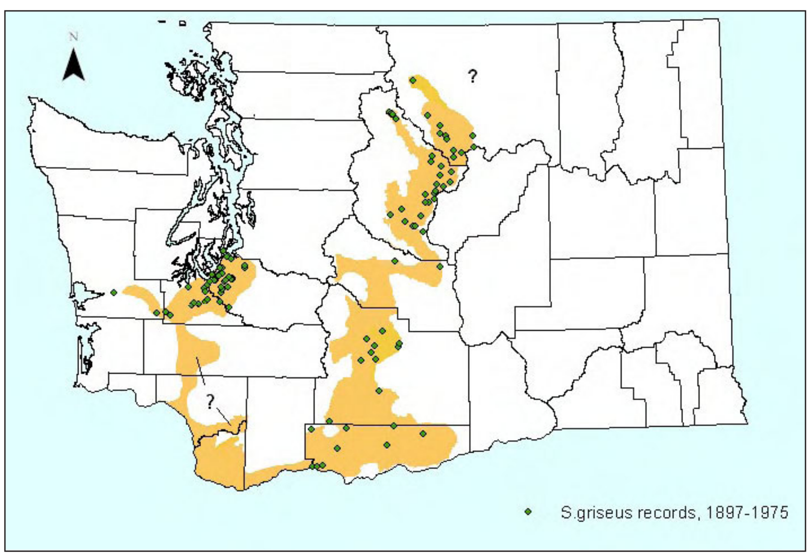


Figure 2. Historic range of the western gray squirrel in Washington. Modified from Booth (1947) and Dalquest (1948) based on habitat and records, 1897-1975.

ington. There are, however, two or more reliable reports of western gray squirrels in Clark County in the last five years. Habitat may have been suitable for western gray squirrels because soil types indicate that small prairies existed and small stands of oak are still scattered throughout much of Clark County and portions of Cowlitz and Lewis County (Chappell et al. 2001). Cassidy (1997) delineated the Willamette Valley and Cowlitz River vegetation zones in these counties and indicated that conifer forest interspersed with Oregon white oak and native prairie was likely the predominant vegetation prior to Euro-American settlement. Booth (1947) went as far as stating that western gray squirrels, "… likely ranged throughout all the Cascades and all of western Washington in the past." Western gray squirrels have not been recorded north of Pierce County in western Washington, but the species might have been able to exist further north if they had reached the oak-conifer woodlands of the San Juan Islands and Vancouver Island, BC. Flahaut (1941) noted that they were seen commonly in Tacoma, but there were no reports of the species near Seattle. Over the past century, their known distribution has been reduced to isolated parts of their former range. By 1975, limited surveys of historic locations in Washington found squirrels only in the southern Puget Trough and in two isolated canyons in Klickitat County (Barnum 1975).

In the Puget Trough, the only remaining western gray squirrel population occurs on and near Fort Lewis Military Reservation and McChord Air Force Base in Pierce County, and perhaps adjacent Thurston County. Most individuals are found on Fort Lewis where the largest remaining concentration of oak and ponderosa pine (*Pinus ponderosa*) in the Puget Trough exists (Rodrick 1986, Ryan and Carey 1995b). Western gray squirrels were observed on McChord Air Force Base (AFB) in 1999 (Bayrakçi 1999), and were detected by hair snag tubes in 2006 (S. Freed, pers. comm.); they have not been confirmed on adjacent private lands for many years (WDFW data system).

In the Klickitat population, western gray squirrels are unevenly distributed from Underwood in Skamania County, east through Klickitat County, and north into Yakima County. They occur in oak-conifer communities along the tributaries of the Columbia River (WDW 1993). In Klickitat County, the highest concentration of squirrels occurs along the Klickitat River and its' tributaries and a remnant group of squirrels occurs in the White Salmon watershed. Scattered occurrences are also distributed throughout the Rock Creek watershed. A few squirrels were observed on the Yakama Reservation in 1998 (WDFW data system); the extent of occupied habitat on the Reservation is uncertain.

Currently, western gray squirrels are patchily distributed in three geographically isolated populations: one in Pierce County in the southern Puget Trough; a second in Klickitat, Yakima, and eastern Skamania counties (hereafter Klickitat); and a third in Chelan and Okanogan Counties in north central Washington (hereafter Okanogan) (Fig. 3). Recent records outside of these areas are rare. These three areas include small portions of the East Cascades, Columbia Plateau, Okanogan, and Willamette Valley-Puget Trough- Georgia Basin ecoregions (WDNR 2003).

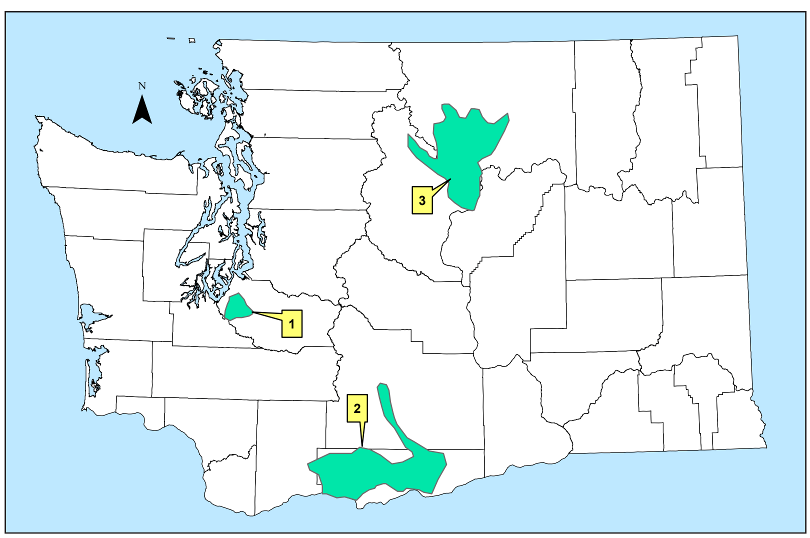


Figure 3. Current distribution of western gray squirrel populations in Washington: 1) Puget Trough; 2) Klickitat; and 3) Okanogan.

The western gray squirrel reaches the northern limit of its range in Okanogan County where it generally occurs in ponderosa pine uplands and riparian areas of mixed conifer and hardwoods. Western gray squirrels are found near the western tip of Lake Chelan in the vicinity of Stehekin, and on the northern shore of Lake Chelan, Chelan County, and in southwestern Okanogan County. The northernmost squirrel locations include Toats Coulee and Mount Hull in north central Okanogan County, and an unconfirmed sighting northwest of Mazama; these outlying observations of squirrels may not represent reproducing or stable populations.

NATURAL HISTORY

Behavior

Arboreal and generally solitary in their habits, western gray squirrels forage on the ground, but rarely stray far from trees (Ingles 1947, Cross 1969, Foster 1992). They avoid large openings, instead using arboreal routes for escape, cover, and access to nest trees (Ingles 1947, Foster 1992). They are adept at arboreal travel and can move rapidly among tree canopies for long distances when canopy conditions permit (Grinnell and Storer 1924). Western gray squirrels are generally secretive and wary by nature, but acclimation to orchards and other areas of human use is known to occur (Bailey 1936, Ryan and Carey 1995a, B. J. Verts, pers. comm.). Rice (1977) found that they were sensitive to human disturbance and generally sought areas secluded from noise and human activity.

During a 17-month study in Klickitat County, 46% of 1,195 initial observations of squirrels were in an "alert" crouch position (M. Linders, pers. obs.); alert postures are a response to perceived threat (Cross 1969). Seasonal variation in alert behavior was also observed, with peaks in the fall and winter, and lows during the spring and summer breeding season. Western gray squirrels in Washington rarely vocalize, but Ingles (1947) states that when alarmed they occasionally utter a series of scolding barks, cha-cha-cha-cha--cha—cha—cha----cha (Ingles 1947); Cross (1969) described it as "chewnnk-chewnnk-chewnnk", emitted rapidly at first and then progressively slower. The calls may be given for up to an hour and may be audible from distances of >180 m (Ingles 1947).

Activity periods. Western gray squirrels vary their activity levels throughout the day and by season, but remain active year-round. The highest levels of activity occur in late autumn when squirrels forage on ripening pine seeds and cache acorns for winter (Grinnell and Storer 1924, Foster 1992, Ryan and Carey 1995a). Warm weather reduces activity to its lowest levels from June to August; at this time squirrels may be seen sprawling along a branch or on top of a leaf nest (Cross 1969, Gilman 1986, Ryan and Carey 1995a, M. Linders, pers. obs.).

Western gray squirrels are primarily diurnal and are most active in the morning hours after sunrise; alternating between periods of activity and rest, they decrease or cease activity late in the day (Ingles 1947, Cross 1969, Gilman 1986). During very stormy or windy weather western gray squirrels may remain near the nest (Grinnell and Storer 1924, Ingles 1947). Several researchers reported increased levels of activity on cloudy days with low wind velocity (Ingles 1947, Packard 1956, Ryan and Carey 1995a). During the shorter days of winter, activity may be reduced to a single period (Cross 1969, Gurnell 1987).

Diet

Hypogeous fungi (truffles and false truffles), pine nuts, acorns, seeds, green vegetation and fruit are the main components of the western gray squirrel diet. In California, these items comprised 90 to 99% of the foods consumed annually; hypogeous fungi averaged >50% of the annual diet by volume (Cross 1969, Stienecker and Browning 1970, Asserson 1974, Stienecker 1977, Byrne 1979). Years of good fungal sporocarp production may buffer the effects of poor production of mast crops (fruit, nuts, or seeds produced by trees). Pine nuts and acorns are considered critical foods because they are very high in oil and moderately high in carbohydrates, which helps increase the development of body fat required by animals prior to the onset of cold weather and breeding (Stienecker and Browning 1970). The availability of these main food resources may influence population density, home range size, the initiation of breeding, and the frequency and severity of mange epidemics (Grinnell and Storer 1924, Ingles 1947, Cross 1969, Barnum 1975, Gurnell 1987, Foster 1992, Cornish et al. 2001). Green vegetation and other foods are consumed during late spring and early summer when few other foods are available (Stienecker 1977), but may be eaten in greater proportions in years of mast failure or fire (Asserson 1974). Gaulke and Gaulke (1984) reported western gray squirrels feeding on immature catkins of aspen (*Populus tremuloides*) at the Oak Creek Wildlife Area in Washington.

Western gray squirrels in Klickitat County dig up and eat larval and adult rain beetles (*Pleocoma* spp.: Superfamily Scarabaeoidea) during late winter and early spring (M. Vander Haegen, pers. comm.). It is not yet known if rain beetles are a significant portion of the diet during that part of the year. Western gray squirrels have also been reported feeding on the cambium of Douglas-fir, ponderosa pine, and maples during winter in the southern Puget Trough, occasionally doing significant damage during years when the squirrels were abundant (Bowles 1921, Scheffer 1952). Gregory (2005) observed debris in her Okanogan study area consistent with western gray squirrel damage, but did not observe squirrels doing it.

Nesting Structures and Use

There are 2 types of stick nests constructed by western gray squirrels. The first is a large, round, covered shelter nest for winter use and rearing young, and the second is a broad platform for seasonal or temporary use (Ingles 1947, Cross 1969, Linders 2000). Both types of nest are built with sticks, twigs, leaves and moss, and lined with grass, moss, lichens and shredded bark. External nest dimensions are 43–91 cm (17 to 36 in) in length and up to 46 cm (18 in) in height (Grinnell and Storer 1924, Ingles 1947, Foster 1992). Foster (1992) reported that most nests observed in northern Oregon were located adjacent to the trunk, in the top third of the nest tree.

Western gray squirrels generally use stick nests for resting and sleeping; 11% (28/263) of nests were in oak cavities; cavities were occasionally used by animals suffering from severe hair loss consistent with symptoms of mange (Linders 2000, Cornish et al. 2001). They frequently use more than one nest each day, and different individuals sometimes occupy the same nest on successive nights. Klickitat squirrels averaged 14.3 ± 1.2 (range 7-28) nests each (Linders 2000), significantly more than the 3.5 nests per squirrel reported for southern Oregon (Cross 1969). In the Okanogan, 12 squirrels used an average of 5.9 ± 1 nests (range 3-14) (Gregory 2005). Cross (1969) reported a significant relationship between social rank and the number of nests used. Access to multiple nests may confer reduced levels of predation, exposure to parasites, and energy expenditure. Forty percent of nests (102/259) in the Klickitat study were used by >1 squirrel (mean of 1.5 squirrels/nest). It is uncommon for two adult western gray squirrels to occupy a nest simultaneously (Cross 1969, Gilman 1986, Linders 2000); doing so may have contributed to the spread of mange in Klickitat County in 1998–1999 (Linders 2000). In the Okanogan study area, most nests (75%, 48/64) were used by only one radio-collared squirrel, and most occasions of nest sharing seemed to be a response to cold weather (Gregory 2005).

Females often use cavity nests for parturition and rearing of young (Ingles 1947, Cross 1969, Gilman 1986). Squirrels may enlarge old woodpecker holes or use cavities formed by decay after tree limbs are lost (Grinnell and Storer 1924, Ingles 1947, Brown 1985). Cavities are lined with soft materials such as shredded bark and grass. On the Klickitat Wildlife Area, nearly all natal dens are in oak cavities; <5% are in stick nests (M. Vander Haegen, pers. comm.). Reproductive females are known to explore and use several cavity nests during the breeding season; they also use stick nests and may change the location of a maternal den during rearing (Cross 1969, Linders 2000). In the Okanogan, fewer cavities may be available as most of 64 active nests were shelters (78%, 50/64) or platforms (20%, 13/64); a natal nest in an alder was the only cavity used (Gregory 2005). Four of 6 females used >1 nest to rear young; 3 used 2 nests, and 1 used 3 nests (Gregory 2005).

Reproduction

Western gray squirrels mate over an extended period ranging from December through June. Female squirrels become sexually mature after 10 or 11 months, and males reach sexual maturity after 1 year (Fletcher 1963, Swift 1977). Male western gray squirrels enter breeding condition by December or January and remain sexually active until late-June or July (Steinecker 1965, Cross 1969, Swift 1977, Foster 1992). Like other tree squirrels, females are in estrous for only 1 day when several males may pursue the female (Gurnell 1987). Most females come into estrous in late-December or January, and some older females go through a second period of estrous in June (Bailey 1936, Fletcher 1963, Foster 1992, Carraway and Verts 1994). The number of pregnant females peaks in February to March, and again in June (Fletcher 1963, Asserson 1974, Swift 1977, Foster 1992), but overall, the breeding season is continuous. Reproductive peaks may result from different age-classes breeding at different times (Bailey 1936, Fletcher 1963), or from responses to seasonal and annual variations in the food supply (Foster 1992, Halloran 1993). Although Fletcher (1963) and others (Steinecker 1965, Maser et al. 1981) believed that older females could produce 2 litters per year, this has never been documented (Cross 1969, Asserson 1974, Foster 1992, Linders 2000, Gregory 2005).

As would be expected given the extended period of reproductive activity, pregnancies can occur from January to October (Bailey 1936, Fletcher 1963, Asserson 1974, Swift 1977, Foster 1992). Young are born after a gestation period of about 44 days (Ingles 1947, Swift 1977). Similar to other tree squirrels, lactation is believed to last approximately 10 weeks (Swift 1977, Gurnell 1987, Weigl et al. 1989). Lactating females were observed from March to August in Klickitat County (M. Linders, pers. obs.), from March to October in northern Oregon (Foster 1992), and from February to October in northern California (Asserson 1974, Swift 1977). Juveniles emerge from nests between March and mid-August (Ingles 1947, Asserson 1974, M. Linders, pers. obs.). Median date of emergence for 29 litters in Klickitat County was 15 June (Vander Haegen et al. 2005).

Litter sizes in Washington are similar to those reported in other parts of the species' range. In California, embryo and litter counts averaged 2.6 young/litter with a range of 1-4, based on 76 litters totaling 197 young (Stephens 1892, Ingles 1947, Fletcher 1963, Asserson 1974, Swift 1977). Based on embryo counts, Swift (1977) found that older females in Butte County, California, had larger mean litter sizes than young females. From 1999 to 2004, litter size in Klickitat County, Washington ranged from 1 to 5, averaging 3.3 ± 0.7 (SD; N = 19) (Vander Haegen et al. 2005). Litter counts represent the number of juveniles observed inside a nest using a remote video camera, prior to emergence. Number of young surviving to emergence from natal dens (approx. 8 weeks of age) averaged 2.5 ± 1.3 (SD; N = 45). Observed differences among embryo counts, litter counts, and emergence counts indicate that some mortality occurs prior to both parturition and weaning.

Longevity, Survival, and Sources of Mortality

No information on longevity is available for western gray squirrels in the wild. Two captive western gray squirrels in California lived for 11 years, and another lived for 8 years (Ross 1930). Longevity of tree squirrels is generally lower in the wild than in captivity, with <1% of individuals ever reaching old age in the wild. For tree squirrels in general, Gurnell (1987) indicates that only about 15 to 25% of young survive to the second year of life. After the first year, annual survival is estimated at 50 to 70%. In good food years, survival can reach 90 to 100% for adults and 50 to 60% for juveniles. In poor food years, survival may drop to <30% for adults with few, if any, young surviving. Measured annual survival rates for radio-collared adult western gray squirrels in Klickitat County from 1999–2003 averaged 57% $\pm$ 6.7 (SD) and ranged from 52–65% (Vander Haegen et al. 2005, M. Linders unpubl. data). Survival rates for juveniles from early fall through entry into the breeding population ranged from 60–86%. Projected 12-month juvenile survival during 2002, the year with the largest sample (n = 16) was 52% (Vander Haegen et al. 2005)

Ingles (1947) identified four sources of western gray squirrel mortality: automobiles; disease; predation; and sport harvest. In Klickitat County, adult males experienced a peak in mortality during late winter/early spring, while females died sporadically throughout the year (Vander Haegen et al. 2005).

Automobiles. Automobiles are an important source of mortality in western gray squirrel populations and are believed to impact them at several times the rate of predation (Ingles 1947, Verts and Carraway 1998, Weston 2005). In Washington, mortality from automobiles regularly occurs at Fort Lewis in Pierce County (Ryan and Carey 1995b), in Klickitat County (M. Linders, pers. obs.; B. Weiler, pers. comm.), and in the Methow Valley in Okanogan County (Bartels 1995, 2000). Roadkill mortality also occurred at Oak Creek Wildlife Area in Yakima County when western gray squirrels were present there (Gaulke and Gaulke 1984).

Disease. Notoedric mange, caused by the mite *Notoedres centrifera* (formerly *N. douglasi*), is the most important disease known to affect western gray squirrel populations and has the potential to reduce their numbers precipitously. It was first known from Bryant's (1921) account in California, where the disease killed large numbers of western gray squirrels at Georgetown Ridge in 1917, on the Shasta, Klamath, and El Dorado national forests in 1920–1921, and in Jamestown, California, in 1920 (Bryant 1921, Shannon 1922, Ross 1930). Ingles (1947) documented an anecdotal account of mange around 1913 near Chico, California that eliminated all squirrels in a 2,400-acre park. These outbreaks drastically reduced populations and by 1926 the western gray squirrel was nearly extinct in the Yosemite Valley (Bryant 1926). As a result, the California hunting season for tree squirrels was closed in 1921 and remained closed until 1946 because of slow recovery (Ingles 1947). The species of mite responsible was not identified until Lavoipierre (1964) reported additional cases from California in the years from 1948–1963. Asserson (1974) found mange in 3% of 425 individuals examined in Kern County, California at non-epidemic levels of occurrence. Mange reached epidemic levels in southern California in the 1970s, which was also a period of prolonged drought (King 2004).

In Washington, outbreaks of mange occurred in Klickitat County in the 1930s and 1998–1999 (Cornish et al. 2001) and in Yakima County in the 1940s (Stream 1993). Klickitat County residents give accounts of one or more epidemics that drastically reduced the population during the 1930s (WDFW, corresp. on file). Mange also decimated squirrels in northern Yakima County by 1950 and the population never recovered (Gaulke and Gaulke 1984, Stream 1993). An outbreak occurred in 1998 and 1999 when 59% of 56 animals captured in Klickitat County had mange and mortality was correspondingly high; 63% of the 30 animals showing signs of mange were found dead or depredated (Linders 2000, Cornish et al. 2001). Squirrels trapped on two additional sites, 2 mi and 20 mi distant also had mange, suggesting that this event was widespread (M. Linders, pers. obs.). Squirrels with mange become emaciated, lack coordination (Shannon 1922, Bryant 1926, Linders 2000) and may have difficulty foraging due to scabs around the eyes (Lavoipierre 1964). Several animals with severe cases died in their nests and many more were depredated, presumably due to their weakened condition (Linders 2000). Mange also can cause abandonment of young, as was observed for two females in Klickitat County, both of which subsequently died; their litters likely perished as well (Vander Haegen et al. 2005). In Klickitat County, the incidence of mange in the population was examined during intensive research-related trapping from 2000–2004 (Vander Haegen et al. 2005). Mange was evident in the population in all years and was most prevalent in late winter and spring. The proportion of animals showing signs of mange averaged 19% in spring and 4% in fall and was greatest in spring of 2003 when 32% of 19 animals captured were infected. Mange has not been observed on Fort Lewis, and Gregory (2005) did not observe symptoms of mange in squirrels at her Okanogan study area during 2003-2005.

Stress and poor nutrition as a result of mast crop failures, drought, or degraded habitat can lower the disease resistance of squirrels and contribute to population declines associated with mange (Lavoipierre 1964, Carlson et al. 1982, Gurnell 1987, King 2004). Nutritional stress likely added to the 1998–1999 outbreak of mange in Klickitat. The outbreak followed a failure of the summer crop of pine seed that significantly impacted squirrels in the area (Cornish et al. 2001). The 1930s epidemic in Klickitat County coincided with the worst drought of the 20th Century, and the 2nd worst drought of the last 250 years (Gedalof et al. 2004). This period of decline of western gray squirrels also roughly coincided with the range expansion of the California ground squirrel. It has been speculated that the California ground squirrel brought the mange organism into Washington and spread it to western gray squirrels. However, *Notoedres centrifera* has not been reported in ground squirrels (H. Klompen, pers. comm.), so this seems unlikely.

In addition to mange, western gray squirrels are susceptible to a number of other diseases and parasites including, coccidiosis, western viral equine encephalitis, West Nile Virus, fleas (Siphonaptera), ticks and mites (Acarina), lice (Anoplura), coccidia (Apicomplexa), intestinal roundworms (Nematoda), ringworm (from fungus *Trichophyton rubrum*), papilloma (Steinecker et al. 1965), and botflies (Ingles 1947, Cross 1969, Carraway and Verts 1994). Only mange and coccidiosis have been implicated in large numbers of squirrel deaths, but, like most diseases afflicting squirrels, little or no detailed work has been done to quantify their effects on squirrel populations (Gurnell 1987). Many of these diseases are linked to ectoparasites and it is believed that squirrels may build multiple nests to lessen their exposure to parasites. Poor food supplies and inclement weather can exacerbate the effects of disease and cause severity to cycle seasonally (Cross 1969, Gurnell 1987). Coccidiosis, prevalent in Los Angeles and Santa Barbara counties in 1930, killed many western gray squirrels (Moffitt 1930). Mites were listed as being present as well, but the die-off was attributed to coccidiosis, which is believed to have also caused declines in Eurasian red squirrels (Gurnell 1987).

West Nile Virus (WNV) affects western gray squirrels, but its importance for squirrel populations is not yet known. Of 64 western gray squirrels tested in California in 2004-05, 39.1% (25) tested positive for WNV (Hamilton 2007). Tree squirrels proved to be useful sentinel for detecting the virus in local areas. Squirrels with West Nile Virus displayed neurological symptoms, including uncoordinated movement, paralysis, shaking, or circling, although other squirrel diseases can produce these symptoms (http://westnile.ca.gov/wnv_squirrels.htm).

Predation. Known predators of western gray squirrels include the red-tailed hawk (*Buteo jamaicensis*), northern goshawk (*Accipiter gentilis*), golden eagle (*Aquila chrysaetos*), coyote (*Canis latrans*), bobcat (*Lynx rufus*), fisher (*Martes pennanti*), and house cat (*Felis silvestris*) (Carraway and Verts 1994, Zielinski et al. 1999, Vander Haegen et al. 2005). Potential predators in the range of western gray squirrels include the marten (*Martes americana*), great horned owl (*Bubo virginianus*), red fox (*Vulpes vulpes*), gray fox (*Urocyon cinereoargenteus*), (Carraway and Verts 1994), domestic dog (*Canis familiaris*) (Ryan and Carey 1995a), and weasels (*Mustela* spp.) (Bayrakçi 1999). There are few data on the impact of predation on western gray squirrel populations. Weasels likely killed several radio-collared eastern gray squirrels on Fort Lewis (Bayrakçi 1999) and seemed to be a significant predator of northern flying squirrels (*Glaucomys sabrinus*) at the same site (Wilson and Carey 1996). In Klickitat County, predation was the major cause of mortality for adults in 3 of 4 years where squirrels were monitored with radio telemetry, while disease was most important in 1999, accounting for at least 40% of mortalities (Vander Haegen et al. 2005). Most depredations in Klickitat County were consistent with bobcat sign, although depredations by northern goshawk, coyote, weasel and an unidentified raptor also occurred (Vander Haegen et al. 2005; M. Linders, pers. obs.).

Population Structure, Density, and Fluctuations

Population structure. Western gray squirrel populations, and tree squirrels in general, are believed to have equal numbers of males and females (Gurnell 1987, Steele and Koprowski 2001). Most trap sampling of adult western gray squirrels has produced male-biased sex ratios (Cross 1969, Asserson 1974, Hall 1980, Foster 1992), but Hall (1980) caught slightly more females in the fall in Lake County, California. In Klickitat County, Washington females seemed to be somewhat more trappable, showing a slightly higher capture frequency in overall trapping efforts (1.0:1.3, n = 174). The sex ratio was equal (1.0:1.0, n = 50) averaged over all seasons (Linders 2000).

Age ratios of western gray squirrels vary with location and from year to year. Age ratios can be indicative of population trends, but this can be affected by confounding factors, such as habitat quality and differential mortality. For example, a large percentage of young can indicate a population increase, unless compensatory mortality is occurring (Allen 1943, Uhlig 1955). Trapping of fox squirrels in Michigan on two sites averaged over five years resulted in 51% immature animals, but ranged from a low of 25% in a year of mast failure, to a high of 74% when the population was increasing (Allen 1943). Hunting samples from 1940–1942 were similar to trapping results (averaged 55% immature squirrels; range 27–79%)(Allen 1943). Working with eastern gray squirrels in West Virginia, Uhlig (1955) analyzed data from 1949–1954 and considered 62% immature animals in the fall hunter harvest to indicate a stable population and he believed variation between sites depended on habitat quality. One high elevation site usually had a high percentage of immatures that compensated for high mortality during winter; a poor quality site showed high variation regardless of population increase or decrease. Allen (1943) found that when the mast crop failed, immature squirrels formed a higher proportion of the animals in open fencerows, whereas adults dominated the higher-quality woodlots; when food supplies were stable, juveniles and adults were equally distributed. Allen (1943) concluded that young-of-the-year were the most vulnerable members of the population, and adult survival is likely less variable.

Hall (1980) conducted a grid-trapping study in Kern County, California and reported that on average immature western gray squirrels (64% of 100 squirrels) outnumbered adults in fall trapping, but the ratios varied among habitats. A fall sample of 422 carcasses provided by the Hunter Cooperation Program in Oregon from 1981 to 1986 was comprised of 34% immatures and 66% adults (Foster 1992). The percentage of immature squirrels in the hunter harvest increased from 29% in 1981–1983 to 46% in 1984–1986. This increase in juveniles followed a population decline in 1983–1984 when hunter-take, an index of population levels, dropped to half of previous levels.

In Washington, the age ratio of 29 squirrels captured in the fall of 1998 in Klickitat County was 34% immatures and 66% adults (Linders 2000). Trapping on the same site in subsequent years indicated the percent of immatures was 42%, 33%, 50% and 25% during 2000, 2001, 2002, and 2003. There was no obvious increase in the percentage of immatures that would be expected following a population decline such as the apparent mange-related decline that occurred in Klickitat County in the winter of 1998–1999.

Population densities. Squirrel densities can vary with season, year, habitat type and quality. Several estimates of density from California ranged from 1.0–2.5/ha (0.40–1.0/ac), (Grinnell and Storer 1924, Asserson 1974, Hall 1980, Gilman 1986). According to Ingles (1947), squirrels in Bidwell Park, Butte County, reached densities of 4.3/ha (1.74/ac) where many non-native mast-producing trees were present. Population density estimates have not been computed for western gray squirrels in Oregon. Direct comparisons between Washington and California are problematic due to possible differences in study methods. However, squirrel densities appear to be much lower in Washington. Density of animals in three study sites in Klickitat County averaged 0.23/ha ($\pm$0.08 SE) and tended to be greater in fall than in spring (Vander Haegen et al. 2005). The lower densities in Washington may be due to habitat quality and quantity and possibly other factors.

Population fluctuations. Little is known about the population dynamics of western gray squirrels. In general, population levels vary as a result of short-term factors including changes in the food supply and random demographic and environmental variation. Overall, tree squirrel numbers fluctuate seasonally and annually, with peak numbers in the fall and early winter, and lower numbers in the spring and early summer (Gurnell 1987, Steele and Koprowski 2001). Variation in the food supply, particularly mast production, has been cited as the most important factor affecting tree squirrel populations, although disease may be inextricably linked (Grinnell and Storer 1924, Lavoipierre 1964, Carlson et al. 1982, Gurnell 1987). Predation and hunting may affect the magnitude of population fluctuations, but rarely cause them. Collectively, mast failures, disease and weather can have a direct or additive effect by delaying the breeding season, reducing the number of females that breed, reducing litter size and survivorship and increasing mortality (Gurnell 1987).

Population fluctuations may be dramatic or gradual. Western gray squirrels increased dramatically between the 1890s and mid-1920s in Pierce County, Washington, but had become scarce within two decades (Bowles 1921, Couch 1926, Booth 1947). In California, >4,000 squirrels reportedly occupied the Yosemite Valley in 1914 and Grinnell and Storer (1924) attributed the high numbers, in part, to government predator control programs. Cross (1969) suggested that short-term cyclic fluctuations might occur among western gray squirrels in southern Oregon. He based this on eight years of squirrel count data from his study site at Emigrant Lake. The population index derived from these counts indicated a 9-fold difference between high and low population levels (Carraway and Verts 1994). Foster (1992) documented a reduction in western gray squirrel numbers from 1981–1987 based on hunter surveys in north central Oregon. She considered low mast production, disease, hunting and logging of mast-producing trees to be contributing factors.

Disease epidemics like notoedric mange can dramatically reduce or eliminate populations of western gray squirrels. In Klickitat County, the western gray squirrel population reportedly crashed in the 1930s as a result of a severe mange epidemic, and long-time residents state the population has never attained its former abundance (WDFW corresp. on file). In California, outbreaks of disease caused extreme population fluctuations and severe declines of western gray squirrels in the Sierra Nevada between 1913 and 1921. Some of these populations did not recover for many years (Stanley 1916, Bryant 1921, 1926, Shannon 1922, Moffitt 1930, Michael 1940, Payne 1940, Sumner and Dixon 1953). Stanley (1916) noted that western gray squirrel numbers in California's Plumas National Forest rebounded within three years after a 1913 disease outbreak killed many squirrels. He attributed recovery to the fact that people became fearful of the disease and stopped hunting squirrels for food.

Home Range, Seasonal Movements, and Dispersal

Home range. Western gray squirrels, and sciurids in general, have home ranges that vary in size, shape, and overlap with sex and season (Ingles 1947, Gilman 1986, Gurnell 1987, Linders 2000). Home range sizes in mammals vary with population density, typical spacing of individuals for the species, foraging behavior, distribution of resources, and habitat selection (Harris et al. 1990, Wauters and Dhondt 1992). Gilman (1986) and Foster (1992) reported that, on average, male and female western gray squirrels used similarly sized home ranges. In contrast, total home range size in Washington differs between sexes, with male home ranges significantly larger than those of females. Linders (2000) noted that seasonal variation in home range size reflects differences in resource use between males and females. During the breeding season females remained closer to the nest while males increased their movements (Linders 2000). Pregnant and lactating females often occupied oak cavities on open oak slopes distant from their central use areas, to which they returned to forage. Ingles (1947) described territorial defense by lactating females, where one-fourth to one-third of the home range is defended against squirrels of both sexes. During the mating period, males maximize their access to females, but may also move widely in search of dispersed foods. Females, however, make more intensive use of high quality habitat in their core areas. Females also had well-defined home ranges that remained stable in time (Linders 2000, Vander Haegen et al. 2005), whereas turnover of males resulted in unstable home range boundaries. Gregory (2005) reported that home ranges in Okanogan County were larger than those in Klickitat County (Table 2). Despite this difference, the 50% core areas of females were

Table 2. Comparison of total[a] 95% fixed kernal home range estimates of western gray squirrels from Klickitat (Linders et al. 2000, Vander Haegen, pers.comm.), and Okanogan counties (Gregory 2005), Washington.

	Mean (ha) $\pm$ SE	SD	N	Home range model	Reference
Females					
Total (Klickitat)	21.9 $\pm$ 2.7	9.4	12	H_{ref} [b]	Linders (2000)
Total (Klickitat)	17.7 $\pm$1.5	8.4	31	H_{LSCV} [c]	Vander Haegen[d]
Total (Okanogan)	49.4 $\pm$ 7.0	19.8	8	H_{LSCV} [c]	Gregory (2005)
Total (Okanogan)	75.2 $\pm$ 11.2	31.7	8	H_{ref} [*b*]	Gregory (2005)
Males					
Total (Klickitat)	73.9 $\pm$ 16.9	50.7	9	H_{ref} [b]	Linders (2000)
Total (Okanogan)	281.0 $\pm$ 25.6	51.2	4	H_{ref} [b]	Gregory (2005)
Total (Okanogan)	142.0 $\pm$ 15.0	30.0	4	H_{LSCV} [c]	Gregory (2005)

[a]Total home range was defined as including all movements for an individual squirrel.
[b]H_{ref} = 95% fixed kernal home range with reference bandwidth smoothing parameter used in home range software.
[c]H_{LSCV} = 95% fixed kernal home range with least-squires cross validation smoothing parameter.
[d]Vander Haegen (pers.comm.), in Gregory (2005).

of similar size (Gregory 2005). She suggested that this may reflect females defending patchy resources such as large productive pines.

The home ranges of western gray squirrels in Washington differ from those in Oregon and California in size, degree of overlap and the degree of size difference between sexes. Home range sizes in Washington were significantly larger than those in Oregon and California (Table 3), and are among the largest reported for a North American tree squirrel (Linders 2000, Gregory 2005). Home range size varies by location, but its estimation is also sensitive to sample size and analysis methods. Most studies of western gray squirrels report small seasonal home ranges (<5 ha [12.4 ac]) based on a few individuals (Ingles 1947, Cross 1969, Asserson 1974, Barnum 1975, Gilman 1986, Foster 1992). The large size of western gray squirrel home ranges in Washington compared to Oregon and California suggest poor habitat quality and low population density (Cross 1969, Don 1983). A large home range increases energy expenditure and exposure to risk, which can reduce fitness and survival (Wauters and Dhondt 1992). Cross (1969) reported larger home ranges in areas with more marginal and unsuitable habitat than in areas with higher quality habitat. Home range size also varies with age, with young animals generally using smaller home ranges than older ones (Cross 1969, Foster 1992, Linders 2000). Washington females exhibit low home range overlap and nearly exclusive core areas (Linders 2000, Gregory 2005, M. Vander Haegen, pers. comm.). Within-sex home range overlap in Klickitat County was lower among females than among males (4.7% vs. 15.1%, 95% minimum convex polygon), and averaged 11% among all animals (mean pairwise overlap of all study animals; Linders 2000, *in* Gregory 2005). Home range (95% fixed kernel) overlap was slightly higher in the Okanogan, averaging 15.8% for all animals; within-sex overlap of female home ranges (7.0%) seemed to be lower than in males (16.5%), but the difference was not significant, possibly due to low sample sizes (Gregory 2005). During the breeding season, males overlapped all other squirrels (63.9%, n = 4) significantly more than did females (6.7%, n = 7). There also is little overlap in core areas of squirrels (Gregory 2005, M. Vander Haegen, pers. comm.). Using similar methods, Gilman (1986) found that mean within-sex overlap among western gray squirrel home ranges in California was 13% for females and 26.9% for males; average overlap among all animals was 24.1% (100% minimum convex polygon).

Seasonal movements and dispersal. Squirrels may disperse permanently in search of a home range, or seasonally in search of good foraging or nesting sites. Western gray squirrels may shift their location in response to the seasonal availability of acorns,

Table 3. Total and seasonal home range estimates for western gray squirrels (100% minimum convex polygon) from Klickitat and Okanogan counties, Washington vs. Oregon and California (Linders et al. 2004, Gregory 2005).

	Oregon and California [a]				Washington					
	Mean (ha)	SE	N	SD	Mean (ha)	SE	N	SD	Study area	*P* [b]
Females										
Total[c]	9.1[d, e]	3.3	6	8.1	31.6	4.7	12	16.3	Klickitat	< 0.01
Total	-	-	-	-	51.8	9.5	8	26.9	Okanogan	
Winter	1.8[d]	0.5	4	1.0	15.4	3.2	7	8.5	Klickitat	< 0.01
Summer	3.9[d,f]	1.1	7	2.9	19.5	2.8	11	9.3	Klickitat	< 0.001
Summer	-	-	-	-	35.5	8.0	7	21.2	Okanogan	
Males										
Total	14.8[d]	2.8	5	6.3	115.9	25.8	9	77.4	Klickitat	< 0.01
	4.4[e]	0.5	4	1.0	-	-	-	-	-	< 0.01
Total	-	-	-	-	255.5	32.1	4	64.2	Okanogan	
Winter	2.9[d]	0.3	3	0.5	30.2	10.4	5	23.3	Klickitat	0.07
Summer	4.8[d]	0.6	6	1.5	37.8	6.6	6	16.2	Klickitat	< 0.01
	2.9[f]	0.2	5	0.4	-	-	-	-	-	< 0.01
Summer	-	-	-	-	85.7	10.7	4	21.4	Okanogan	

[a]Data are combined for females in Oregon and California but not for males due to significant differences in home range size between studies.
[b]P-values from Mann-Whitney tests.
[c]Total home range was defined as including all movements for an individual squirrel.
[d]Cross (1969), Oregon.
[e]Foster (1992), Oregon.
[f]Gilman (1986), California.

pine nuts and other foods or to take advantage of breeding opportunities (M. Linders, pers. obs.). An adult female squirrel in Klickitat County shifted her home range >600 m within 1 month of capture to an area which had been vacated by another squirrel; a month later, she moved a similar distance before disappearing. She was relocated 6 months later in a patch of ponderosa pine at the bottom of a canyon 4 km (2.5 mi) away. The following spring she returned to the top of the canyon to raise a litter of young. In winter, she returned to the canyon bottom before radio contact was lost (M. Vander Haegen, pers. comm.).

Breeding females generally reduce their movements during the mating season to remain closer to the maternal nest, while males travel farther in search of females (Don 1983, Gurnell 1987, Linders 2000). In Klickitat County, females often established maternal dens on open oak slopes away from core areas, but returned to core areas to forage (Linders 2000). Males often traveled up to 1.7 km (1.1 mi) between successive locations, and sometimes moved >5 km a day in search of females (Cross 1969, Linders 2000.).

In Klickitat County, twenty percent of 30 radio-tagged juvenile squirrels dispersed off of the study area where they were captured in their first autumn (Vander Haegen et al. 2005). Mean dispersal distance was 2,862 m $\pm$ 213 (SD, N = 6), although it was unclear if these measures represented final dispersal distances; 5 of the 6 dispersing animals died or disappeared (probable radio failure) within months of dispersing.

Ecological Relationships

Ecological function. Western gray squirrels and other small mammals perform important ecological functions in oak-conifer communities by dispersing the spores of hypogeous fungi (Maser et al. 1981). Hypogeous fungi are ectomycorrhizal associates of pine, oak, and Douglas-fir, and act to increase water and nutrient uptake by tree roots. Western gray squirrels consume large quantities of truffles, the below-ground fruiting bodies (sporocarps) of mycorrhizal fungi. Spores contained in truffles pass through the gut and are dispersed as squirrels defecate. These spores wash into the soil and inoculate the roots of trees. The fungi then serve as hosts to nitrogen-fixing bacteria, which convert atmospheric nitrogen into a form that is used by both the tree and the fungi. Certain hypogeous fungi are unique to oaks, and may help prepare nitrogen-poor grassland soils for invasion by oaks (A. Carey, pers. comm.). This functional relationship works to sustain the oak woodland ecosystem by maintaining a productive soil environment (Maser et al. 1981). Oak woodlands are used by approximately 200 species of birds, mammals, reptiles and amphibians, and at least 70 species of invertebrates (Larsen and Morgan 1998).

The importance of western gray squirrels for seed dispersal of Oregon white oak has not been studied, but germination data indicate that animal dispersal is important for both red and white oak species (Smallwood et al. 2003). Western gray squirrels may facilitate oak propagation by collecting acorns and burying them outside the spread of the parent tree. While other small mammals may cache acorns, the habit of burying acorns individually in small holes is a trait primarily displayed by squirrels in the genus *Sciurus*. The squirrels do not recover all of the acorns, so those left in the ground may germinate and become seedlings (Smith 1970).

Western gray squirrels are known to eat rain beetles, but it is not known if western gray squirrel predation has a significant impact on rain beetle populations. Rain beetle larvae feed on the roots of trees including oaks, ponderosa pine, Douglas-fir, maples, and sagebrush, and sometimes damage apple, pear and cherry orchards.

Competition with other native species. Many species may compete for food with western gray squirrels; however, because most native species have co-existed for a long period of time they are believed to impact squirrels less than introduced species. Competition from native tree squirrels including Douglas' squirrels (*Tamiasciurus douglasii*), red squirrels (*Tamiasciurus hudsonicus*) and northern flying squirrels could impact western gray squirrels because these species have similar diets and nest sites. Some studies hypothesize that both interference and exploitation competition exist between western gray squirrels and Douglas' squirrels (Ingles 1947, Cross 1969, Barnum 1975, Rodrick 1986). Interference competition occurs when organisms actively defend or control limited resources, while exploitation competition refers to the passive depletion of resources. Although Douglas' squirrels inhabit a mix of deciduous-coniferous forests, their primary habitat is conifer forest (Smith 1970, Carey 1991). The Douglas' squirrel is a conifer seed specialist, but will make use of hazelnuts and acorns, especially during years of conifer mast failure. Few Douglas' squirrels were captured on the Fort Lewis sites studied by Bayrakçi (1999), but continued encroachment of Douglas-fir into oak ecotones would likely favor this squirrel. The encroachment of Douglas-fir into stands of pine and oak as a consequence of fire exclusion may have led to an increase in the number of Douglas squirrels in some locations. Red squirrels overlap with western gray squirrels in the Okanogan, where they may compete for Douglas-fir and pine seeds (Gregory 2005).

Northern flying squirrels are nocturnal, and co-occurr with western gray squirrels wherever nest cavities are available. Both species consume large quantities of hypogeous fungi, but may avoid direct conflict by dividing access to resources in time. Flying squirrels used oak cavities for denning on Fort Lewis, where they were trapped in 9 of 22 stands studied (Bayrakçi 1999).

The California ground squirrel (*Spermophilus beecheyi*) is a recent potential competitor that did not occur in Washington until the 20th century. It was first reported in Washington in 1912, and it is not known how it arrived in the state (Booth 1947). They reportedly increased in number with the construction of new dams and bridges on the Columbia River (WDW 1993). This species has expanded rapidly along the eastern Cascade Mountains and is known to consume acorns, an important food of the western gray squirrel (Foster 1992, Verts and Carraway 1998). The California ground squirrel may exhibit both interference and exploitation competition with western gray squirrels. According to long-time residents in Klickitat County, western gray squirrel numbers decreased as California ground squirrels increased (D. Morrison, pers. comm.), although it is unknown if there was a causal relationship. The ranges of western gray squirrels and California ground squirrels in California and Oregon exhibit nearly complete overlap. Apparently habitat separation, or other niche differences have long allowed them to coexist. In Washington, California ground squirrels seem to use more open habitats than western gray squirrels, and they hibernate during fall and early winter when food supplies are still relatively abundant. Expansion of the range of California ground squirrels into western gray squirrel habitats may be facilitated by logging because they colonize clearcuts and use slash piles and roadbanks as burrow sites.

Other native species with the potential to compete for food with the western gray squirrel include Cascade golden-mantled ground squirrel (*Spermophilus saturatus*), yellow pine chipmunk (*Eutamias amoenus*), acorn woodpecker (*Melanerpes formicivorus*), Lewis' woodpecker (*M. lewis*), American crow (*Corvus brachyrhynchos*), scrub jay (*Aphelocoma coerulescens*), Stellar's jay (*Cyanocitta stelleri*), northern flicker (*Colaptes cafer*), striped skunk (*Mephitis mephitis*), dusky-footed woodrat (*Neotoma fuscipes*), mule deer (*Odocoileus hemionus hemionus*), black-tailed deer (*O. h. columbianus*), and porcupine (*Erethizon dorsatum*; Cross 1969, Barnum 1975, Gilman 1986, WDW 1993).

Competition with introduced species. Merriam's turkey (*Meleagris gallopavo*), eastern gray squirrel, and eastern fox squirrel are introduced species that likely compete with western gray squirrels; their combined ranges overlap extensively with the historic range of western gray squirrels in Washington. Like western gray squirrels, eastern gray and fox squirrels are diurnal and appear to compete directly for some of the same food and nest resources (Byrne 1979). Eastern gray squirrels were introduced to Woodland Park in Seattle in 1925 (Dalquest 1948). Seven pairs were brought from Minneapolis, Minnesota, and after release, quickly spread around Green Lake and to the shores of Lake Washington (Flahaut 1941, Dalquest 1948). Since that time, eastern gray squirrels have spread to many Washington cities.

Fox squirrels were introduced into Washington at least three times, the first in about 1915. Yocum (1950) cites a letter from Steve Black, who was a U.S. Fish and Wildlife Service predator control agent stationed in Clarkston, that a total of 12 pairs of fox squirrels from the eastern U.S. where liberated at three locations in Asotin County, including along Asotin Creek and George Creek. In the 1940s, Willis Irwin, an employee of Washington Department of Natural Resources, brought fox squirrels from Missouri and released them in Okanogan County at the confluence of the Similkameen and Okanogan rivers (Stream 1993). The fox squirrels reportedly dispersed south along the Okanogan River after release. Most recently, 12 fox squirrels were liberated in Pioneer Park in Walla Walla in 1964 by the then head of the Walla Walla Parks Department, who had seen them in Philadelphia, Pennsylvania (M. Denny, pers. comm.). Fox squirrels have now invaded every drainage on the western edge of the Blue Mountains up to 2,200 ft elevation. They can also be found in all towns along the northwestern front of the Blue Mountains from Pomeroy, Washington, to Ukiah, Oregon. They have been reported damaging apple buds in orchards around Milton-Freewater and Weston, Oregon (M. Denny, pers. comm.). Evidently fox squirrels are being transported and released illegally because they are present in Othello, Adams County, (D. Stinson, pers. obs.), and have also recently been reported in Wahkiakum County and on Orcas Island in the San Juan Islands. The fox squirrel produces 2 litters per year, has a broader diet, and greater juvenile dispersal than western gray squirrels, allowing them to thrive in highly developed urban and suburban areas (King 2004).

The eastern gray squirrel is listed by the World Conservation Union (IUCN) among the world's 100 worst invasive species (Lowe et al. 2000). Eastern gray squirrels were introduced as pets in Great Britain and Italy, and have since replaced the native European red squirrel (*Sciurus vulgaris* L.) in much of Britain, Ireland, and northern Italy (Rushton et al. 2002, Bertolino and Genovesi

2003). At study locations in northern England and northern Italy, eastern gray squirrels cause a reduction in body growth of juvenile and subadult red squirrels, and they compete for seeds cached by adult red squirrels (Gurnell et al. 2004). Where gray squirrels were present, female red squirrels had a lower body mass and fewer of them produced two litters per year. The presence of gray squirrels resulted in reduced red squirrel reproduction and recruitment, and is expected to result in population decline and eventual extinction (Gurnell et al. 2004). Ongoing control programs in Great Britain and Italy are intended to reduce gray squirrel populations to protect red squirrel populations and reduce bark-stripping damage by gray squirrels (Rushton et al. 2002, Bertolino and Genovesi 2003, Mayle et al. 2004). Koprowski (2005) indicated that eastern gray squirrels are able to live in much smaller habitat fragments and at higher densities than are native European red squirrels. Also, the eastern gray squirrel's tolerance for nesting in groups and the female's tendency to remain in natal areas to form overlapping generations of kin may partly explain their ability to displace the solitary European red squirrel (Koprowski 2005).

The impact of eastern gray and fox squirrels on native squirrels in western North America has received little study. In north central California, Byrne (1979) found that introduced eastern gray and fox squirrels did not cause a major displacement of western gray squirrels, but replaced them in some riparian areas, perhaps by sheer force of numbers. The eastern gray squirrels were more successful in some moist woodlands, but they did not become established in the drier uplands occupied by western gray squirrels (Byrne 1979). A recent study in southern California reported that the fox squirrel thrives in suburban habitats, but has been unable to invade the drier, undeveloped oak/conifer forests in the area's national forests (King 2004). Western gray squirrels prevailed in 75% of aggressive interactions with fox squirrels (King 2004). During good crop years, Byrne (1979) reported that introduced squirrels maintained a twice-yearly breeding cycle, while western gray squirrels only bred once. Eastern grays may be unable to produce a second litter in the drier woodland, and thus lose this advantage over western gray squirrels (Byrne 1979). Both western gray squirrels and the introduced squirrels ate cultivated nuts and fruits. Eastern gray and fox squirrels made greater use of black walnuts which are native to California but have been spread by human activities (Byrne 1979). Western gray squirrels ate more hypogeous fungi than eastern gray squirrels; this may have been a result of habitat, because fungi seemed to be rare in the riparian areas used by eastern gray and fox squirrels.

In the northern Willamette Valley of Oregon where fox, eastern gray, and western gray squirrels co-occur, eastern gray squirrels appear to be largely confined to the urban Portland area, where western gray squirrels are absent (Verts and Carraway 1998, Weston 2005). The fox squirrels appeared to be dependent on nut orchards; orchards or cultivated nut trees were present at 75% of the sites where they were observed. Fox squirrels appeared to be expanding their range into areas where nut trees provide additional food (Weston 2005). Local farmers reported that, "when the red (fox) squirrel moved in, the gray (western) squirrel moved out." It is not certain if this is the result of competition, or changes in habitat that eliminated western gray squirrels, but were tolerated by fox squirrels.

The ability of eastern gray squirrels to live in suburban environments may give them an advantage in developing areas where western gray squirrels are found; the presence of eastern gray squirrels likely negatively impacts marginal western gray squirrel populations. Most of the habitats used by introduced squirrels in California have been altered by human influence, but both the eastern gray and fox squirrel live in some habitats that are some distance from suburban and agricultural development (Byrne 1979).

There is potential for competition between introduced wild turkeys and western gray squirrels where they overlap. Wild turkeys, which have been successfully introduced into oak and pine habitats in Klickitat, Okanogan and Chelan counties and the Puget Trough, eat two of the three main foods that western gray squirrels depend on (pine nuts and acorns). Wild turkeys congregate where fallen pine seeds and acorns are abundant (Rumble and Anderson 1996, USDA-NRCS 2004). No research has been conducted on the potential for competition between western gray squirrels and wild turkeys.

HABITAT REQUIREMENTS

Forest Types

The western gray squirrel inhabits mast-producing conifer-hardwood forest types throughout its range. In Washington, western gray squirrels are associated with transitional forests of ponderosa pine, Oregon white oak, Douglas-fir and various riparian tree species. While the majority of these habitats contain trees of the pine and oak genera, the presence of both is not essential. High tree species diversity is a common component of western gray squirrel habitat and contributes to habitat quality (Ryan and Carey 1995b, Linders 2000). Mixed deciduous-conifer habitat types are naturally fragmented by slope, aspect, and elevation, creating a mosaic of habitats that vary in their suitability for western gray squirrels. Habitat quality in Washington is thought to be relatively poor compared to other parts of the species' range due to a lower number of large-seeded, mast-bearing tree species. Additional species available to western gray squirrels in California and southern Oregon include valley oak (*Quercus lobata*), California black oak (*Q. kelloggi*), blue oak (*Q. douglasi*), live oak (*Q. agrifolia*), Brewer oak (*Q. breweri*), black walnut (*Juglans hindsii*), Jeffrey pine (*Pinus jeffreyi*), knobcone pine (*P. attenuata*), digger pine (*P. sabiniana*), sugar pine (*P. lambertiana*), Coulter pine (*P. coulteri*) Monterey cypress (*Cupressus macrocarpa*), and California bay (*Umbellularia californica*) (Ingles 1947, Steinecker and Browning 1970, Steinbecker 1977, Foster 1992).

The specific composition and structure of habitat is distinct in each of the three geographic regions occupied by squirrels in Washington. In the Klickitat region, habitat for western gray squirrels occurs where oak woodlands and pine forests converge. Squirrels are associated with stands of Oregon white oak, ponderosa pine, Douglas-fir, and riparian areas that include bigleaf maple (*Acer macrophylum*), Oregon ash (*Fraxinus latifolia*), black cottonwood (*Populus trichocarpa*), and quaking aspen (*Populus tremuloides*). Understory shrubs include hazelnut (*Corylus cornuta*), vine maple (*Acer circinatum*), snowberry (*Symphoricarpos albus*), deerbrush (*Ceanothus intergerrimus*), oceanspray (*Holodiscus discolor*), poison oak (*Toxicodendron diversilobum)*, and bitterbrush (*Purshia tridentata*).

In the Puget Trough, western gray squirrels occur in oak-conifer ecotones between upland Douglas-fir forests of the Western Hemlock (*Tsuga heterophylla*) Zone and prairies. These areas consist primarily of Oregon white oak and Douglas-fir, but may include Oregon ash, bitter cherry (*Prunus emarginata*), cascara (*Rhamnus purshiana*), and bigleaf maple. Prominent shrub species include Indian plum (*Oemleria cerasiformes*), snowberry, Oregon grape (*Berberis aquifolium*), and hazelnut.

Western gray squirrels in the Okanogan use stands of ponderosa pine and Douglas-fir and adjacent riparian black cottonwoods (Bartels 1995, Gregory 2005, Hamer et al. 2005). Gregory (2005) studied western gray squirrels in forests of the ponderosa pine/bitterbrush and ponderosa pine/bitterbrush-snowbrush (*Ceonothus velutinus*) plant associations described by Franklin and Dyrness (1988). Common mast-producing species include Douglas maple (*Acer douglasii*), vine maple, bigleaf maple, hazelnut, oceanspray, blue elderberry (*Sambucus cerulea*), huckleberry (*Vaccinium* spp.), snowberry and serviceberry (*Amelanchier alnifolia*). Squirrels in the Stehekin Valley and near the northwest tip of Lake Chelan are in stands dominated by Douglas-fir, bigleaf maple and ponderosa pine, with smaller numbers of western red cedar, red alder, and black cottonwood (Hamer et al. 2005). The forest of the Stehekin Valley floor is within the Douglas-fir zone of eastern Washington (Franklin and Dyrness 1988), but the species assemblage appears to be transitional between western and eastern Washington (Hamer et al. 2005).

Vegetation types that may contain western gray squirrel habitat. A statewide map of vegetation types that may contain suitable western gray squirrel habitat was developed using data from the Habitat-Relationships in Oregon and Washington project (Johnson and O'Neil 2001), and Washington

Department of Natural Resources (WDNR) Natural Heritage Program. On the east slope of the Cascade Mountains, western gray squirrels are associated with the wildlife habitat types classified by Johnson and O'Neil (2001) as Ponderosa Pine Forest and Woodlands, (including Eastside Oak). Western gray squirrels extend into riparian areas and upward into low elevation Eastside Mixed Conifer Forest, but limitations of the data did not allow these areas to be included in the map. Habitat west of the Cascade Mountains is of the Westside Oak and Dry Douglas-fir Forest and Woodland habitat type, but also includes adjacent areas of the Woodland/Prairie Mosaic Zone identified by the Washington GAP Analysis Project (Johnson and Cassidy 1997) and Chappel et al. (2001). These layers were combined and the resulting layer was clipped at the outer extent of known historical and recent squirrel distribution (e.g. ponderosa pine habitat on the eastside occurs all the way to Idaho; Fig. 4). The lower edge of the Ponderosa Pine Forest and Woodland type was buffered to pull in just the edge of the next lower zone, since it appeared to be underestimating habitat in places based on observations in the field. These vegetation zones and wildlife habitat types are broad representations that may contain suitable western gray squirrel habitat.

Mixed deciduous-conifer forest particularly in riparian areas between Klickitat County and Vancouver, Clark County, and between Vancouver and the Puget Trough should perhaps be included in the map; however, no data illustrating the distribution of these cover types was available. These habitats would be included in the Willamette Valley and Cowlitz River zones described by Cassidy (1997) which have different soils and support more deciduous and mixed vegetation than the surrounding conifer zones. Further refinement and ground-truthing at a finer scale will be needed to identify suitable habitat for planning surveys and habitat management activities.

Stand Characteristics

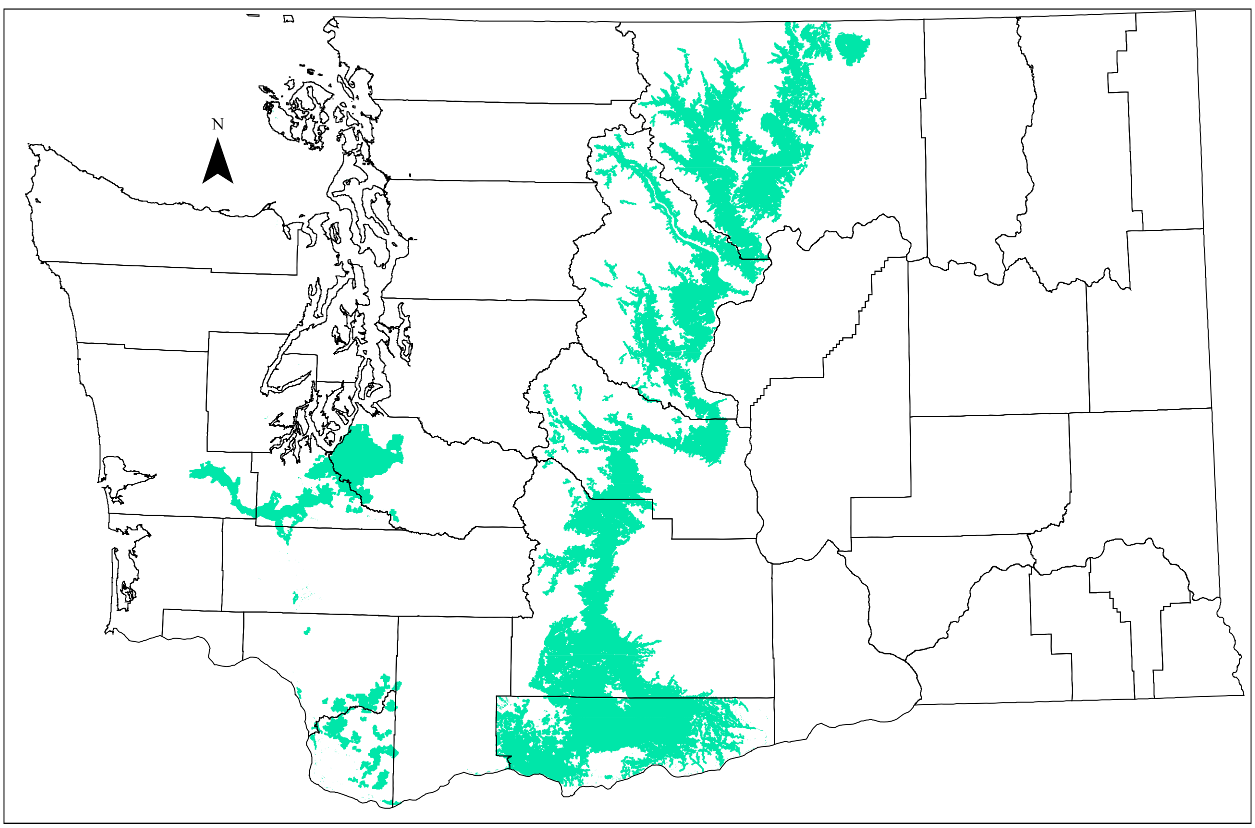


Figure 4. Vegetation types in Washington that may contain suitable western gray squirrel habitat (additional area of habitat may exist in Cowlitz, and Lewis counties).

Suitable western gray squirrel habitat generally consists of conifer-dominated stands of mature mast-producing trees usually of pine and oak. Western gray squirrels have been found to select mixed conifer/deciduous stands that are conifer-dominated (55–77%) as measured by both canopy cover and stem density (Byrne 1979, Hall 1980, Gilman 1986, Ryan and Carey 1995b, Linders 2000, Gregory 2005). A diversity of tree species, and in most areas the presence of oak, were also important habitat components. Sites with more large-diameter trees (>15 in) may be an important factor in improving reproductive fitness, because large trees provide more food and better cover than small trees, as reported for Abert's squirrel (Patton et al. 1985, Dodd et al. 1998, Dodd et al. 2003), and are more likely to provide nest cavities as well. To meet basic requirements, western gray squirrel habitat must provide nuts, seeds, and fungi, an interconnected canopy for arboreal travel and escape, and protected locations for nesting, foraging, and reproduction (Gilman 1986, Foster 1992, Ryan and Carey 1995b). In some cases these needs may be met by traveling between different stand types to take advantage of seasonally available foods.

In Washington, stand characteristics of western gray squirrel habitat have been studied in the Puget Trough (Ryan and Carey 1995a), Klickitat (Linders 2000), and Okanogan (Gregory 2005, Hamer et al. 2005) regions. On the Fort Lewis Military Reservation in the Puget Trough, western gray squirrel presence was positively correlated with mixed oak-conifer stands >8 ha (19.8 ac) in size that were ≤600 m from water. Squirrels favored stands containing a greater abundance and diversity of food-bearing trees and shrubs, and mixed stands over pure oak stands (Ryan and Carey 1995a). High-use stands had significantly more basal area in Douglas-fir, more young oak trees, lower average ground cover, and more coarse woody debris. Bowles (1921) noted that western gray squirrel habitat in the Puget Trough was relatively free of shrubby undergrowth. Ryan and Carey (1995b) reported that high-use stands had lower average shrub cover than low-use stands (41.9 vs. 50%; n = 26), although differences were not statistically significant.

In Klickitat County, western gray squirrels favored conifer-dominated stands over mixed oak-conifer and pure oak stands at the home range scale (Linders 2000). Site characteristics where western gray squirrels were observed typically had a pine overstory with an open understory. Vegetation descriptions were collected at 1,872 locations where both radio-collared and uncollared squirrels were observed in Klickitat County. Stands used most often by western gray squirrels were dominated by a multi-layered canopy of ponderosa pine that had an upper canopy layer taller than 14 m (46 ft) and a sparse understory of oak with little or no shrub cover or other ground vegetation. Pine was the most frequently used tree for nesting, foraging, and cover (Linders 2000).

Squirrels on the Klickitat study area selected for moderate conifer (25–75% canopy cover) at the home range scale and for moderate and dense (>75% canopy cover) conifer (>75% conifer) cover-types at the 80% core area scale. Using radio telemetry fixes, there was selection only for moderate conifer cover types. These cover types were favored over sparse conifer (<25% canopy cover), pure oak (>75% oak) and mixed oak-conifer cover-types at all levels of canopy cover (Linders 2000). Selection for the conifer cover-type differs from Ryan and Carey (1995b), and Gilman's (1986) California study in which western gray squirrels favored a mixed oak-conifer cover type (60% knobcone pine, 40% black oak). In eastern Washington, ponderosa pine might provide a more reliable food supply and more complete cover than the lower-growing Oregon white oak (Linders 2000). Six pregnant and lactating females in the Klickitat study area also showed heavy use of the moderate density oak cover type, where oak cavities provided good maternal nest sites (Linders 2000).

Stand characteristics in nest and core areas used by western gray squirrels in Klickitat County were nearly identical (Table 4; Figs. 5, 6; n = 88). Core areas were defined by the 65% fixed kernel contour of their home range. Core plots had more small pines, which is reflected in the lower total stem density and slightly higher mean dbh of nest plots (Linders 2000)

Table 4. Stand density (mean, standard error, standard deviation) and tree diameter on western gray squirrel nest plots and core area plots in Klickitat County, Washington, 1998–1999 (Linders 2000).

Stand characteristics	Nest plots (n = 100)			Core area[a] plots (n = 88)		
	Mean	SE	SD	Mean	SE	SD
Number of trees/ha[b]	474	21	210	583	24	225.1
Number of pines/ha[c]	330	22	220	406	25	234.5
Number of oaks/ha[c]	110	9	90	144	12	112.6
Number of firs/ha	34	8	80	33	8	75.0
Mean dbh[d] (cm)[e]	24.2	0.2	2	23.0	0.2	1.9
Mean dbh pine (cm)[e]	25.6	0.3	3	24.3	0.2	1.9
Mean dbh oak (cm)	17.8	0.3	3	17.4	0.3	2.8
Mean dbh fir (cm)	31.7	1.1	11	31.2	1.1	10.3
Mean basal area (m^2/ha)	23.8	5.5	58.2	26.3	6.9	95.1

[a]Core area is defined by the 65% fixed kernel contour of their home range.
[b]Significantly different at $P < 0.01$.
[c]Significantly different at $P < 0.05$.
[d]Dbh = tree diameter at breast height.
[e]Significantly different at $P < 0.001$.

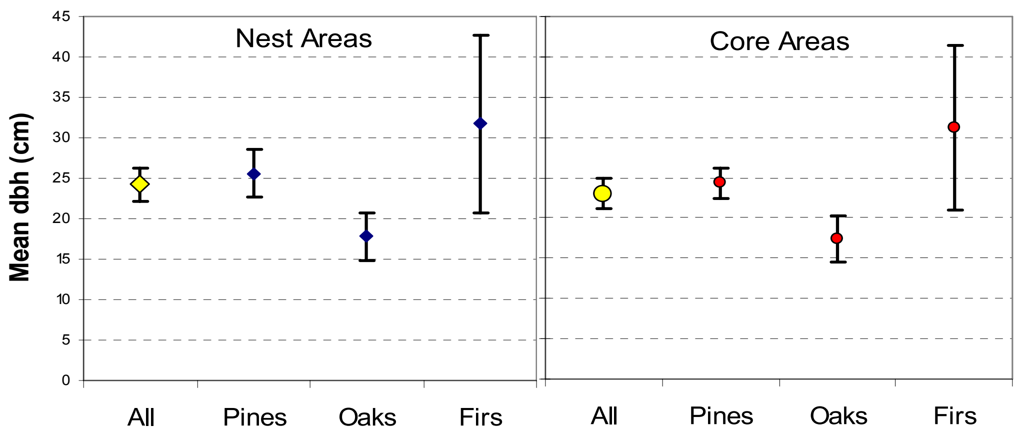


Figure 5. Mean dbh (+ SD) of pine, oak, Douglas-fir, and all species in western gray squirrel nest areas and core areas on the Klickitat Wildlife Area (Linders 2000).

Mean basal area was 26.3 m^2/ha in core areas and 23.8 m^2/ha in nest sites in Klickitat County (Linders 2000). In Okanogan County, mean basal area of 50 nest tree plots was 27 m^2/ha (SE = 1.7), nearly twice that of control plots (14.7, SE = 1.1) (Gregory 2005). The average basal areas reported from squirrel home ranges in Washington were lower than those reported by Hall (1980) and Garrison et al. (2005) in California (Table 5). Ryan and Carey (1995b) reported higher squirrel use of stands with higher basal area. Basal area may be positively correlated with habitat quality for western gray squirrels up to a point where competition reduces the health of trees, or the age of trees affects mast production. Dodd et al. (1998) described population source areas for Abert's squirrel as having basal area of >35 m^2/ha, >20 trees/ha of 45.7 – 61.0 cm dbh, (152 ft^2/ac, >8.1 trees per ac 18-24 in dbh) and >22 patches/ha of >5 interlocking canopy trees. Nest site selection and the greater mast associated with larger trees suggest that the high basal area of high quality habitat would have a significant component of large trees rather than a high density of small diameter trees.

Measures of canopy cover, ground cover, coarse woody debris, and stand density were similar between nest and core plots (Linders 2000). Nest and

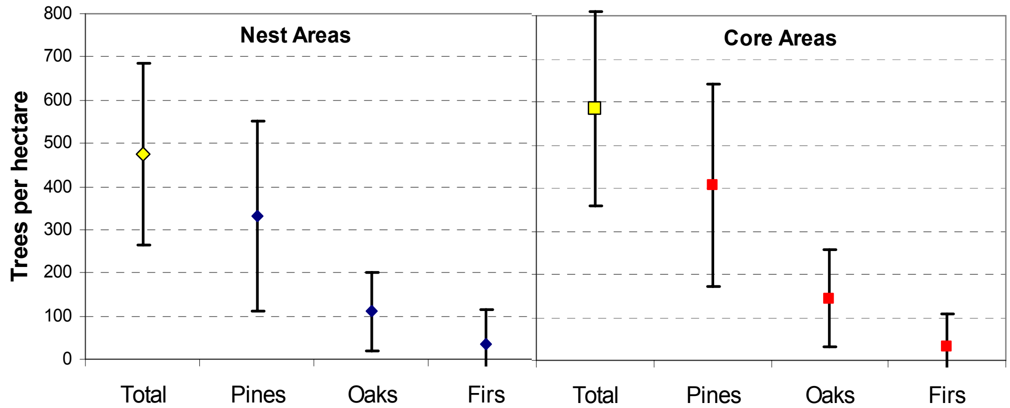


Figure 6. Mean density (+ SD) of pine, oak, Douglas-fir, and all species in western gray squirrel nest areas and core areas on the Klickitat Wildlife Area (Linders 2000).

Table 5. Basal area, tree density, and proportion of trees by genera in stands used by western gray squirrels in California, Oregon, and Washington (modified from Linders 2000).

Habitat	Site	N[a]	BA[a] m^2/ha	Trees/ ha	Pine %	Oak %	D-fir %	Other %	Reference
GENERAL[b]									
Core areas	WA	88	26.3	474	69.6	23.2	7.2	0.0	Linders (2000)
High use	WA	18	27.0	244	0.0	34.1	53.3	12.6[c]	Ryan & Carey (1995b)
Moderate use	WA	12	22.2	217	0.0	43.6	51.9	4.5	Ryan & Carey (1995b)
Low/no use[d]	WA	26	16.2	215	0.0	52.5	43.0	4.8	Ryan & Carey (1995b)
Mixed conifer[e]	CA	10	34.0[f]	349	26.4	25.2	34.4	14.0	Hall (1980)
Ponderosa pine[e]	CA	10	34.0[f]	403	85.1	7.9	5. 0	2.0	Hall (1980)
Knobcone pine[e]	CA	10	85.0[f]	843	40.3	51.5	0.0	8.2	Hall (1980)
Black oak	CA	4	35.8	254	58.7[g]	40.9[h]	NA	NA	Garrison et al. (2005)
Black oak	CA	4	39.3	252	51.6[g]	47.6[h]	NA	NA	Garrison et al. (2005)
NESTING									
Nest sites	WA	100	23.8	583	69.6	24.7	5.7	0.0	Linders (2000)
Nest sites	WA	50	27.2	432	77.7	0.0	18.6	3.7[i]	Gregory (2005)
Nest sites	OR	21	-	983	54.9	26.4	9.5	0.4	Foster (1992)

[a]N is number of plots; BA is basal area.
[b]General habitats from Hall (1980) are in order of decreasing habitat quality based on squirrel density; general habitats from Ryan and Carey (1995b) are in order of decreasing habitat quality based on squirrel sightings.
[c] Includes western red cedar (*Thuja plicata*).
[d]Western gray squirrels were not observed using these stands.
[e]Squirrel density differed by habitat: mixed conifer> knobcone pine (adults and immatures); ponderosa pine >knobcone pine (adults only).
[f] Basal area from Hall (1980) $\pm$ 1 percent.
[g]Percent conifer, mostly ponderosa pine but included some Douglas-fir, white fir (*Abies concolor*), sugar pine, and incense cedar (*Calocedrus decurrens*).
[h]Percent hardwood, mostly California black oak.
[i]Deciduous species.

core plots were combined to form one set of values that characterize western gray squirrel "primary" areas, or those parts of the home range where squirrels spend the majority of their time foraging and nesting (Table 6; Fig. 7). Linders (2000) found that the ground at squirrel sites in Klickitat County averaged >75% forest litter with little ground vegetation of any kind. Ground vegetation generally decreases with increasing canopy cover and an open understory may allow squirrels to better avoid danger while on the ground. Higher canopy cover is also positively associated with higher production of underground fungal sporocarps (Lehmkuhl et al. 2004), an important food of western gray squirrels.

Table 6. Measures of canopy cover, ground cover, stand composition, and coarse woody debris on western gray squirrel primary areas (combined nest and core area plots) in Klickitat County, Washington (Linders 2000).

Stand characteristics	Mean (n = 302)	SE	SD
CANOPY COVER			
% Cover in pine	32	1.1	19.1
% Cover in oak	16	0.9	1.6
% Cover in fir	7	1.0	17.4
% Total cover	54	1.1	19.1
Average # interlocking crowns[a]	2.9	0.1	1.7
GROUND COVER			
% Litter	75.6	1.0	17.4
% Shrubs	7.5	0.6	10.4
% Grass	6.8	0.7	12.2
% Moss	3.9	0.4	6.9
% Forbs, ferns, seedlings, rock, bare	5.1[b]		
STAND DENSITY AND DECAY			
Sapling density (#/ha)	126	7	121.6
Basal area (m^2/ha)	25.4	4.6	79.9
Coarse woody debris class I (tons/ha)	5.02	0.37	6.4
Coarse woody debris class II (tons/ha)	3.04	0.26	4.5

[a]Average number of crowns within 1 m ("interlocking") random overstory trees.
[b] Forbs, ferns, seedlings, rock, and bare ground have been combined; see Linders (2000) for %.

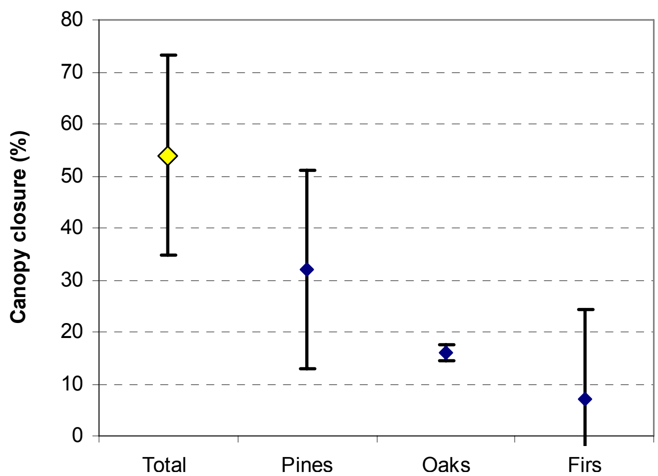


Figure 7. Mean (+ SD) percent canopy closure and percent in pine, oak, and Douglas-fir in western gray squirrel primary areas on the Klickitat Wildlife Area (Linders 2000).

Gregory (2005) sampled habitat around nest sites in a 1,300 ha study area in the Black Canyon watershed in the Okanogan, where western gray squirrel populations exist beyond the range of Oregon white oak. The likelihood of a site being chosen for nesting increased with basal area, dbh, and increasing species diversity. Mean canopy cover of nest plots was 45% (SE = 3) compared with 30% (SE = 2) for control plots (Gregory 2005).

Hamer et al. (2005) sampled 10.6 m diameter nest plots at 28 western gray squirrel nest trees in the Stehekin Valley, Chelan County. Canopy cover was estimated visually and categorized as >5-25%, >25-50%, >50-75%, and >75%. Most (24/28; 86%) plots were classed as >25-50 or >50-75% canopy cover (3 were >5-25; 1 was >75%). Douglas-fir, bigleaf maple, and ponderosa pine accounted for most trees (>10 cm) in plots (Table 7).

Herbaceous cover was sparse in plots, with grasses, litter, and woody debris the most prevalent cover types. Nearly all plots (26/28) had shrub cover in <25% cover categories; most (21) had ≤ 5% cover, and 7 plots had no shrub cover (Hamer et al. 2005). About two-thirds of plots had shrubs that produced fruits that may be eaten by squirrels; the most common species were blackberries/raspberries (*Rubus* spp.), Oregon grape, and Pacific dogwood (*Cornus nutallii*).

Nest Trees

Western gray squirrels frequently nest in conifer trees that are >40 cm (15.8 in) in dbh, with dominant or codominant crowns, and a marginal or interior stand position (Byrne 1979, Foster 1992, Linders 2000, Gregory 2005, Hamer et al. 2005). Cavities in oaks, cottonwoods, or alder are often used for natal nests when available (Bartels 2000, Linders 2000, Gregory 2005). Most nest trees have crowns that connect (<1 m separation) with surrounding trees providing a means of arboreal travel. Nest tree characteristics are similar across the range of the western gray squirrel (Byrne 1979, Gilman 1986, Foster 1992, Gregory 2005).

In Klickitat County, western gray squirrels nested in large conifers more often than expected based on the size and composition of trees in surrounding stands. Of 263 active nest trees, 72% were pine, 16% were fir, and 12% were oak (Linders 2000).

Table 7. Mean dbh of trees (>10 cm) in 28 western gray squirrel nest plots in the Stehekin Valley, North Cascades National Park (Hamer et al. 2005).

Species	n	Mean dbh cm (in)
Douglas-fir	158	41.6 (16.4)
Bigleaf maple	36	21.7 (8.5)
Ponderosa pine	28	46.4 (18.3)
Red alder	11	40.5 (15.9)
Pacific dogwood	7	13.1 (5.2)
Western red cedar	4	68.5 (27.0)
Black cottonwood	3	61.0 (24.0)
Grand fir[a]	2	124.0 (48.8)
Total	247	39.6 (15.6)

[a]*Abies grandis*

Nest trees did not reflect random selection of available trees. Pine and fir were used more than expected for nesting, while oak was used less than expected. The mean dbh of 110 nest trees measured was 40.3 ± 1.3 cm for pine (range = 15.6–77.7; n = 79), 46.3 ± 4.1 cm for oak (range = 24.5–65.3; n = 11; cavities only), and 47.7 ± 2.8 cm for fir (range = 19.1–62.4; n = 20) [means: pine = 15.9 in; oak = 18.2 in; fir = 18.8 in]. All species of nest trees had significantly larger mean stem diameters than trees in surrounding plots. Most nest trees (103 of 112) had crowns that were codominant (73%), or dominant (19%) in the nest stand. None of the 112 nests had crowns that were isolated. Squirrels selected trees in the interior (56%) or at the edge (26%) of a stand. Twenty nest trees had an isolated stand position (i.e. were open grown), but still had crowns that connected with other trees. Of the 20, six were oaks with cavities used as maternal dens; the 14 remaining trees were a mix of species, and 10 were used by females believed to be pregnant or lactating at the time (Linders 2000). The mean number of tree crowns interlocking with nest trees was 4.1 ± 0.2 and was significantly greater than found at random trees in surrounding plots (2.9 ± 0.1). A structural deformity was present at the nest in 29% of nest trees; these were most often broken or dead tops of conifers or cavities in oaks.

In Okanogan County, the variables that appeared to be the most important in selection of a nest tree were mistletoe infection, dbh, and connectivity (Gregory 2005). Most of 64 active nests were in ponderosa pine (81%) or Douglas-fir (16%) (Gregory 2005). Of 89 nests found by Bartels (2000), 63% were in Douglas-fir, 31% were in ponderosa pine, and 3% were in black cottonwood. Similarly, in the Stehekin Valley, Hamer et al. (2005) reported that 64% of nests (18 of 28) were in Douglas-fir, 29% (8) in ponderosa pine, and 7% (2) in black cottonwood. Hamer et al. (2005) reported that the mean number of crowns connecting with 28 nest trees was 4.2 (range 0-8, SD = 2.1), while the mean for 112 non-nest trees was 3.4 (SD = 2.0). The mean dbh of nest trees was 65 cm (36-124 cm, SD = 20); 89% (25/28) were >40 cm (Hamer et al. 2005).

Gregory (2005) reported that the mean number of crowns connecting with nest trees was 2.7, and the mean dbh was 45±1.8 cm; 66% (33/50) were >40 cm (range 22-84, n = 50). Nest trees had greater dbh and connectivity values than control trees. Nest trees exhibited less connectivity than in Klickitat County; many nest trees were too far from surrounding trees to allow arboreal travel, and individuals were observed traveling on the ground. Of 11 natal nests, 3 had no canopy connection with surrounding trees, and 3 connected with only 1 other tree (Gregory 2005).

Most natal dens of radio-collared females on the Klickitat Wildlife Area were in oak cavities (M. Vander Haegen, pers. comm.). Most of 39 natal den trees found using telemetry were vigorous, with >75% live crown, and only 3 (8%) were snags. Den trees averaged 43.4 (±1.51 SE) cm dbh (17.1 in) and 9.84 (±0.53 SE) m in height. The minimum dbh selected was 28 cm (11 in), and the shortest den tree was 4 m in height. The average number of live crowns touching the crown of the den tree was 3.2 (±0.32 SE).

Gregory (2005) reported that half of nest trees (25/50) exhibited brooms associated with mistletoe infections, compared to 7% for control trees. The increased branching in trees with mistletoe brooms seemed to attract squirrels for nesting, and the odds of a squirrel choosing a tree for nesting increased with the degree of infection. The majority of trees with natal nests (6/10) had some degree of extra branching due to mistletoe, which may provide added concealment sought by the female for her young (Gregory 2005). Abert's squirrel also uses mistletoe brooms for nesting and caching food. Garnett et al. (2006) reported that 17% of brooms examined (39 of 226) showed evidence of use by Abert's squirrel including 8 nests. Of 40 Abert's squirrel nests described by Farentinos (1972), 10 were in large mistletoe brooms.

Proximity to water. Western gray squirrels may prefer to have a year-round source of fresh drinking water (Foster 1992). In the Puget Trough, this species has been found to select forested stands within 600 m of permanent water (Ryan and Carey 1995b). In Okanogan County, Gregory (2005) reported that nests were an average of 582 m (range 20-1,230) from perennial water, and it did not seem to be an important variable. In Wasco County, Oregon, Foster (1992) found that nest trees were usually within 180 m of water. While the literature suggests that squirrels may have the ability to exist for long periods without water (Keith 1965), this has not been studied for the western gray squirrel. Most radio-collared squirrels in Klickitat County very rarely visited a water source and most water needs may be met by their food and by lapping dew (M. Linders, pers. obs.).

Foraging Habitat and Factors Affecting Food Availability

Food supply is the most important factor regulating tree squirrel populations (Gurnell 1987), so optimal habitat for western gray squirrels would provide an abundance of pine seeds, acorns, and hypogeous fungi. The presence of a diversity of other seeds and fruits, such as maples, hazelnuts, Oregon ash, serviceberry, and Indian plum, may help to provide a more stable food supply over time. Large diameter trees generally produce more seeds or acorns, while an interconnected canopy provides for arboreal travel and security for squirrels. Site factors affecting fungi, seed, and acorn production include canopy closure, stand density, understory competition, soil moisture and fertility, and fire.

Pine seeds may be the most reliable food for squirrel populations in the Klickitat and Okanogan regions. In ponderosa pine, tree diameter is considered the most important determinant of the frequency and size of cone crops at the level of the individual tree (Krannitz and Duralia 2004). The frequency of cone production increases with tree diameter up to around 32 in (80 cm), where it levels off (Krannitz and Duralia 2004). Understory competition also affects cone production by reducing diameter growth and vigor of trees (Krannitz and Duralia 2004). In a 16-year California study, all ponderosa pines over 26 inches dbh (66 cm) produced at least some cones, whereas only 13% of trees in the 3.6–7.9 inch (9.1–19.1 cm) range produced cones during that period (Fowells and Schubert 1956). Most (>90%) trees ≥20 inches dbh (51 cm) produced cones at least once during the study and only trees ≥20 inches produced crops of ≥500 cones. In general, each 10-inch (25 cm) increase in diameter resulted in a doubling of the cone crop, with 38-inch (97-cm) trees producing an average of 200 cones per tree (Fowells and Schubert 1956). Within the dominant crown class, the average number of cones per tree per crop generally leveled off or declined for trees >38 in (96.5 cm).

Crown dominance also plays a role in seed production of ponderosa pine (Krannitz and Duralia 2004). In California, ponderosa pines with a dominant crown position produced 99% of the cones over a 16-yr period (Fowells and Schubert 1956), a relationship attributed to increased leaf mass (Krannitz and Duralia 2004). Not all dominant trees were good producers, however, and a relationship between cone production, crown size and vigor did not emerge until analysis was restricted to trees that produced at least 500 cones. On average, dominant trees with diameters between 7.6 and 11.5 inches (19.3–29.2 cm) produced cones only once in 16 years, but trees >24 inches (61 cm) produced cones 10 times (Fowells and Schubert 1956). In general, basal area and stem density of the stand are negatively associated with seed production per tree (Krannitz and Duralia 2004); "open" stands produced nearly 3 times as many cones per tree as "dense" stands (Pearson 1912), but no data are available on the relationship between numbers of cones per acre for dense stands vs. open stands. However, isolated ponderosa pines self-pollinate at a higher frequency, and self pollinated cones bear a lower percentage of filled seeds (Sorensen and Miles 1974). Also, seedlings from lower density stands are more inbred and have lower heterozygosity and survival ability (Farris and Mitton 1984). Fowells and Schubert (1956) found a linear relationship between number of seeds per acre and volume of trees having isolated or dominant crowns comprising at least 65% of total tree height, and good to moderate vigor.

Underground fungi make up a large portion of the diet of western gray squirrels, and are probably a critical resource in years of poor mast production. Lehmkuhl et al. (2004) reported a positive correlation between truffle abundance and canopy closure and woody debris cover in stands in eastern Washington that included open ponderosa pine and mixed montane conifer stands. States and Gaud (1997) reported that stand structure dramatically affected hypogeous sporocarp production in ponderosa pine forest in Arizona. Canopy cover and basal area were positively associated with increased sporocarp production in all stands except those dominated by saplings. Reduction of canopy cover and basal area by timber harvest resulted in reductions in sporocarp production, but harvests designed to retain clustered trees (light and moderate harvests) showed a smaller decline. Reduction of canopy cover and disturbance of the litter layer during harvest may have reduced soil moisture resulting in lower sporocarp production (States and Gaud 1997). Intermediate aged stands (pole and sawtimber) exhibited higher production of sporocarps compared to stands dominated by saplings or 'overmature' pines ($\geq$ 65 cm dbh) (Table 8).

Management may reduce truffle abundance but not affect species diversity, at least in western Washington Douglas-fir forest. Carey et al. (2002) investigated truffle abundance in second-growth Douglas-fir stands on Fort Lewis in the southern Puget Sound area. They found no significant difference in sporocarp production between stands that had been clearcut in 1927 and lightly thinned twice since, compared with stands that had been harvested circa 1937 that retained about 6 old-growth trees and were not subsequently thinned. Truffle diversity of these second growth stands was similar, but biomass of sporocarps was low (1-4.5 kg/ha vs. 0.5 kg/ha), compared to natural forests of the Olympic Penninsula and the northern Cascades (Carey et al. 2002).

Acorns are an important resource for most western gray squirrel populations, but Oregon white oaks do not produce large acorn crops every year. Anecdotal information suggests that years with heavy acorn crops are followed by one or more poor mast years, and that productivity is somewhat synchronized across the region (Peter and Harrington 2002). Acorn production is affected by competition, moisture, tree age, and fire history. Oregon white oaks are extremely slow-growing and do not produce acorns until at least 20 years old; maximum productivity is not achieved until 80 years of age (Peter and Harrington 2002). Oregon white oak produce acorns mostly on branch tips exposed to full sun. Peter and Harrington (2002)

Table 8. Canopy cover, basal area, and estimated hypogeous fungi sporocarp biomass of ponderosa pine stands in Arizona (modified from States and Gaud 1997).

Stand type	Recent management	Canopy cover %	Basal area (m^2/ha)	Sporocarp biomass (kg/ha)
Closed canopy sapling[a]	none	82.0	65.1	0.15
Mixed age	light harvest[b]	62.5	28.7	0.81
Mixed age	moderate harvest[b]	56.0	23.5	0.31
Mixed age	heavy harvest[c]	27.0	12.8	0.02
Closed canopy blackjack[d]	none	78.0	34.0	1.25
Virgin mixed age[e]	none	59.5	27.4	0.58

[a]Sapling stands were primarily 5-10.9 cm dbh
[b]Stand selectively harvested for older age-class trees with retention of clustered tree distribution.
[c]Stand harvested without retention of clustered tree distribution.
[d]Blackjack: diameter distribution was 43.2 % in the 11-24.9 cm class, 18.1 % in the 25-49.9 cm class, and 36.4% sapling (5-10.9cm).
[e]This stand contained the highest percentage (14.6%) of old pines ≥65 cm dbh.

noted that higher percent crown contact and basal area of surrounding stands reduced acorn production of sample trees. Open-grown trees are better acorn producers than crowded trees, but it is not known what level of stand density would produce the most acorns per unit area (Peter and Harrington 2002).

Western Gray Squirrel Habitat and Characteristics of Pre-settlement Ponderosa Pine Forest

Historical accounts suggest that prior to the influences of Euro-American settlement, ponderosa pine forests were more open, with more large trees, much lower average stem densities and canopy closure. It has generally been assumed that the historical pine landscape was predominantly old forest, maintained by frequent low severity surface fires. However, a recent historical reconstruction study by Hessburg et al. (2007) suggested that stands of old forest with park-like conditions were not abundant, and that intermediate and young forest structures and a mixed severity fire regime may have dominated the dry forest landscape. The landscape would have had patches and stands of various ages. Clumping of trees likely provided patches of higher canopy closure that provided sites for western gray squirrel nests and sites of higher fungal sporocarp production. Harrod et al. (1999) indicates that these more open, but clumped pre-settlement pine forests were likely at low-risk to crown fire and bark beetle attack. Pole and mature aged stands seem to contain more squirrel nests and may be more suitable for nesting than old growth stands with very low tree density and very large trees (>36") with the lowest branches at great height (S. Van Leuven, pers. comm.). It may be safe to assume that the pre-settlement landscape that included a patchy matrix of clumps of old growth, mature, and younger trees was suitable for western gray squirrels.

Ideal foraging habitat for western gray squirrels may reflect a balance between open conditions that encourage acorn and pine seed production, and clumping of trees that allows arboreal travel by squirrels, secure nesting sites, and that provides patches of high canopy closure that would produce abundant fungal sporocarps. Western gray squirrels sometimes forage in stands that provide seasonal or an occasional abundance of food (e.g. oak woodland), while nesting elsewhere in conifers with better cover. Optimal habitat would provide conditions suitable for both foraging and nesting.

Optimal habitat for western gray squirrels has not been described, and optimal habitat for the three regions in Washington would differ somewhat because the Okanogan lacks the oak component, and the Puget Trough habitat contains more Douglas-fir. Below is a tentative list of desirable characteristics for western gray squirrel habitat; details can be found in Appendix B. Where data are lacking, we considered data for Abert's squirrel habitat in

Arizona ponderosa pine. These characteristics do not necessarily represent optimal habitat.

- Multi-aged ponderosa pine-dominated stands of oak-conifer forest.
- Low to moderate stem density (360-685 trees per ha/ 145-277 per ac) with clumped distribution providing nest sites and canopy connections for arboreal travel within clumps and between some clumps; greater clumping and connecting stringers needed at the lower canopy closures.
- More than 20 large (>15" or 38.1 cm dbh) pine or oak per hectare (8 /ac)
- Ground cover mostly in litter and grass; sparse understory in scattered shrubs.
- A few scattered older cavity trees (e.g. oaks, cottonwoods, etc.).
- Presence of additional food species within the annual home range, such as bigleaf maple, vine maple, California hazelnut, Oregon ash, Indian plum, serviceberry, or aspen; species will differ with region.

Based on high use stands from Ryan and Carey (1995b), desirable characteristics of habitat in the south Puget Sound region would include:

- Mixed stands of Douglas-fir and oak (average dbh of Douglas-fir 19.1 inches [48.5 cm])
- Open understory with patches of shrubs.
- A few scattered older oaks with cavities.
- 6–10 tree and shrub species present that produce seeds or fruits eaten by western gray squirrels (including: snowberry, hazelnut, Indian plum, Douglas-fir, Oregon white oak, salal (*Gaultheria shallon*), serviceberry, *Rosa* spp., blackberry, red huckleberry, *Ribes* spp., bigleaf maple, vine maple, Oregon ash, ponderosa pine, cascara, Pacific yew (*Taxus brevifolia*), grand fir, Pacific dogwood, black cottonwood)

POPULATION STATUS

California

Western gray squirrel numbers in California have varied dramatically over the past 150 years. In the mid-1800s, unregulated market hunting significantly impacted squirrel populations (CDFG 2000). Hunting seasons became regulated locally in the late 1800s, but did not come under state control until 1895. The western gray squirrel was removed from the list of game animals in 1923 due to extreme reductions in its numbers and hunting seasons remained closed until 1946 (Ingles 1947). The number of western gray squirrels taken annually by hunters increased from 40,300 in 1954 to 251,000 in 1971 (Asserson 1974). Hunting mortality for western gray squirrels in 1998 was estimated at 72,558 squirrels including crippling loss (CDFG 2000).

In the past, biologists from the California Department of Fish and Game conducted line transect surveys for tree squirrels in the summer, and hunter bag checks in the fall to estimate squirrel abundance and assess overall health. No formal western gray squirrel surveys or hunter bag checks are currently conducted in California (P. Lauridson, pers. comm.). The spring breeding population of western gray squirrels was estimated at 18 million (range 6–30 million) in 1999 (CDFG 2000).

Oregon

The western gray squirrel is more common in Oregon than in Washington, but has shown signs of decline in recent decades, particularly in the northern portion of the state (Foster 1992, Weston 2005). A 1969 report estimated that 5,400 hunters of big game or game birds killed 21,760 squirrels that year (Oregon Game Division Annual Report 1969, *in* Verts and Carraway 1998). Oregon State Game Commission data showed that by 1981 hunter numbers had more than doubled and hunter take had increased to 50,524, while the area thought to be occupied by western gray squirrels declined by >28% (Verts and Carraway 1998). As in California, the Oregon Department of Fish and Wildlife does not conduct surveys to monitor population trends of western gray squirrels. A study of western gray squirrels in the Columbia River Gorge area of Oregon opposite Klickitat County, Washington, documented a population decline between 1983 and 1987 (Foster 1992). Weston (2005) reported that western gray squirrels appeared to be extirpated from portions of the northern Willamette Valley. Squirrel sighting data collected during annual spring deer surveys over the past 40 years suggest that western gray squirrel populations in southern Oregon have been declining gradually over time (M. Wolfer, pers. comm.).

Washington: Past

Little information is available on historical population levels of the western gray squirrel in Washington. In 1805, Lewis and Clark noted that robes made from western gray squirrel pelts were worn by indigenous people in the Columbia River Gorge (Thwaites 1904), suggesting that squirrels occurred in reasonable numbers.

Western gray squirrels in the southern Puget Trough were considered uncommon during the late 1800s due to hunting pressure (Bowles 1921). Until 1933, county governments regulated hunting, and seasons were often long and bag limits were rarely set (Appendix C). Changes in the location and timing of hunting seasons suggest that tree squirrel populations were not very stable. Bowles (1921) described an immense increase in western gray squirrels in Pierce County, Washington, between 1896 and 1920 that he attributed to reduced hunting pressure and an expansion of forests into Puget Sound prairies. Both Bowles (1921) and Couch (1926) described the species as common in the Pierce County area, and bark stripping by squirrels for food resulted in significant damage to trees. Western gray squirrels were frequently seen in Tacoma in 1941 (Flahaut 1941), and were more common in Pierce than in Klickitat County (Booth 1947). Western gray squirrels were still present in the suburbs of Tacoma in the early 1950s, but declined with increasing development (M. Johnson, pers. comm., *in* Rodrick 1986).

Okanogan County opened a hunting season for gray squirrels in 1928. However, western gray squirrels apparently were not abundant because the season was closed in 1929. J. Patterson (*in* Stream 1993) indicated that the western gray squirrel expanded its range north along the Okanogan River during the 1940s, when walnut trees planted by settlers between 1915 and 1920 came of age. Hard winters and indiscriminate shooting may have prevented the population from increasing during the 1960s (Stream 1993; WDFW files).

In 1938, western gray squirrels were common in the oaks along Highway 12 in Yakima County (Scheffer 1957). Booth (1947) described them as uncommon in the southern Cascade Mountains. Squirrels were frequently sighted near Ahtanum and Cowiche Creeks, and less commonly along Oak Creek in Yakima County. An outbreak of mange decimated squirrels in this area by 1950 and they never recovered (Gaulke and Gaulke 1984, Stream 1993).

In 1939, H. Orcutt reported that past hunting had “reduced numbers severely” in the area around Dryden, southeast of Leavenworth, Chelan County (Scheffer 1957), and eastside hunting was restricted to Klickitat County. Lauckart (1970) mentions a severe die-off in the early 1940s that he attributed to mange. By the late 1940s, western gray squirrels had again become scarce and were seldom seen across much of their Washington range (Booth 1947). Fall seasons were permitted intermittently until 1943 and have remained closed since that time, except for a localized control hunt in Pierce and Thurston counties in 1949 and 1950 (Appendix C).

In 1970, the species was included in a brochure on rare mammals of Washington, where its status was described as most numerous in oak woods, but spotty and scarce elsewhere in its range (Lauckhart 1970). D. Morrison (pers. comm.) remembers seeing western gray squirrels on the Klickitat Wildlife Area when he started work there in 1973. He considered them uncommon and felt numbers had remained stable on the wildlife area since that time. Records indicate that this species was still relatively widely distributed in the southern Puget Trough through the 1970s (Barnum 1975; WDFW data system). Barnum (1975) conducted a limited study on the status and distribution of the western gray squirrel in Washington. During 135 hours of surveys, Barnum visited sites near Twisp, Chelan, Yakima, Goldendale, Vancouver, and the southern Puget Trough, but he did not conduct systematic surveys. He observed only 1 squirrel in the southern Puget Sound area, with all remaining observations located near Goldendale in Klickitat County. Barnum (1975) concluded that western gray squirrels had become increasingly rare, and remaining populations were isolated relicts restricted to a few locations in the State. Western gray squirrels were last observed in southern Thurston County in the late 1970s (WDW 1993).

Rodrick (1986) conducted surveys using baited track stations in the Puget Trough in 1985–1986, and found western gray squirrel sign on just 4 of 26 sites (15%); Fort Lewis appeared to harbor the last remaining squirrels in the Puget Trough. Only 3 of 10 historical sites surveyed in Klickitat County in 1985–1986 had western gray squirrel sign (Rodrick 1986).

Washington Department of Game (WDFW) biologist Ellis Bohay reintroduced 10 western gray squirrels from south of Portland, Oregon, to the WDFW Oak Creek Wildlife Area: 3 in August 1970; 7 in September 1971 (Stream 1993). The squirrels reproduced for several years at Oak Creek where they were fed corn out of feed boxes during the winter. The supplemental winter feeding was discontinued after several years. In 1984, Gaulke and Gaulke (1984) conducted a population census at Oak Creek. In 125 hours, 39 squirrel sightings were recorded along a two-mile stretch of road and were thought to represent about 10 individuals. No active nest sites were found. This population was believed to be very small and isolated. Western gray squirrels were last observed in the Oak Creek area in 1989 (Stream 1993). Logging, historical grazing, road-kill hazard, habitat degradation by wintering elk, and incidental shooting, all affected conditions there (Stream 1993, Bayrakçi 1999), but a founder population of only 10 squirrels may have had a low chance of persisting even under ideal conditions.

Washington: Present

Surveys conducted from 1994-2004, incidental records, and cumulative negative data indicate that the majority of western gray squirrels currently in the state are in Klickitat County. Smaller numbers of squirrels are known to occur in Yakima, Skamania, Chelan, and Okanogan counties and a small remnant population occurs in Pierce County (Fig. 8). The Pierce County population is very small and has declined significantly in the last 10 years. In the Okanogan, western gray squirrels are found around Lake Chelan in Chelan County and in southwestern Okanogan County; their numbers appear to be relatively small, though additional surveys are needed. A small number of squirrels is also known to occur on the Yakama Reservation in Yakima County.

Several historic locations, such as Thurston County, Grays Harbor County, northern Yakima County and southern Chelan County, appear to no longer have squirrel populations (Fig. 8, WDFW data system). Evidence of squirrel absence in portions of their historic range is the product of both surveys and the absence of incidental observations. Older squirrel records, in particular, were the result of incidental sightings by staff and other biologists and road kills. There is an absence of incidental records in the last 10 years outside of the 3 known population areas, despite the collective number of people in the field. While difficult to quantify, there are 1,000s of staff-days in the field in all parts of the state by hundreds of agency staff, foresters, and knowledgeable people each year. Biologists from WDFW, tribal agencies, and non-governmental organizations evaluate forest practice applications, survey streams, and conduct research throughout the state and most would report sightings of western gray squirrels both inside, and particularly outside, the 3 population areas. Though there are certain areas that deserve additional survey effort, and pockets of habitat that may contain western gray squirrels, it is likely that the current distribution maps account for the vast majority of western gray squirrels in Washington.

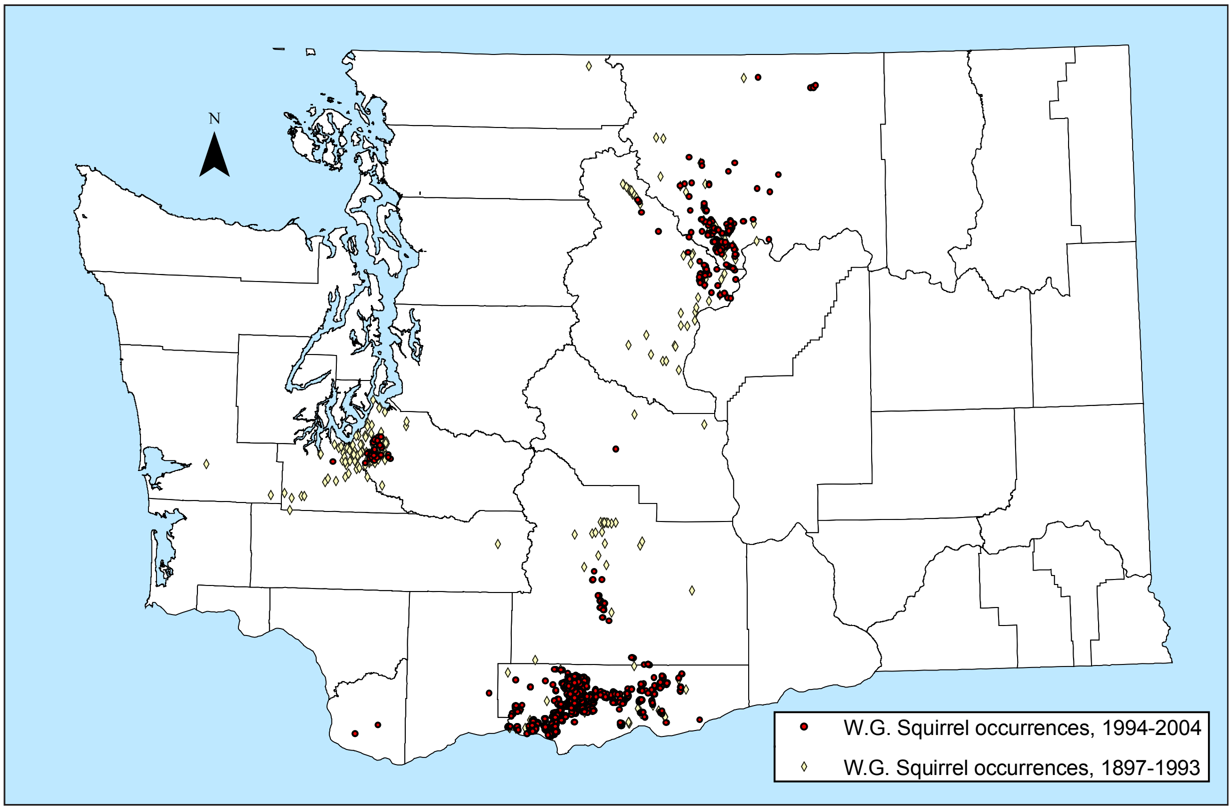


Figure 8. Western gray squirrel occurrences (nests and squirrels) in Washington before 1994, and 1994-2004.

Surveys. Limited surveys conducted prior to the 1990s relied on observation (Barnum 1974), trapping (Barnum 1974, Foster 1992) and baited track plates (Rodrick 1986) and were generally conducted in areas where squirrels were known to occur historically. Western gray squirrels are difficult to observe because of their reclusive nature and limited vocalization and trapping and track plate techniques are not efficient detection methods in areas with low squirrel density. S. Foster (pers. comm.) developed another technique that could be used over large areas. She determined that, in addition to observations, western gray squirrels could be effectively surveyed by looking for signs of foraging, nest-building, and multiple stick nests concentrated within several acres.

Surveys initiated in the early 1990s represented the first extensive survey and habitat mapping effort for western gray squirrels in Washington. These began with intensive surveys conducted on Fort Lewis in 1992–1993 (Ryan and Carey 1995b) and McChord AFB in Pierce County (TNC & WNHP 1996). Surveys in 1994–1997 focused on western gray squirrel populations in Klickitat County and the Okanogan. The 1992–1997 survey efforts were supplemented in subsequent years by additional surveys on Fort Lewis in 1998–1999 and 2004 (Bayrakçi et al. 2001, Fimbel 2004b), and in Okanogan County in 2000 (Bartels 1995, 2000). Numerous sites in Klickitat and adjacent parts of Skamania County were surveyed in response to forest practice applications for logging activities, and in search of study sites from 1998–2002.

During >12,000 hours of surveys in 1994–2002 there were a total of 2,153 detections of squirrels (281) or nests (1,872) (Table 9). Of all detections statewide, 87% occurred in Klickitat County, 12% were in the Okanogan and 1% in the Puget Trough.

Klickitat surveys. Intensive, widespread surveys conducted on both public and private lands between 1994 and 1996 greatly expanded existing

Table 9. Survey effort, survey area, and number of western gray squirrel occurrences (squirrels and nests) in three regions of Washington, 1994 to 2002.

Region	Survey hrs[a]	Area (ha)	Occurrences			
			Squirrels	Nests	Total	
					n	%
Klickitat	7,300	25,383[b]	131	1,734	1,865[c]	87
Okanogan	804	10,603[d]	125	136	261	12
Puget Trough	4,400	[439][e]	25	2[f]	27	1[f]
Statewide	12,504	36,539	281	1,872	2,153	100

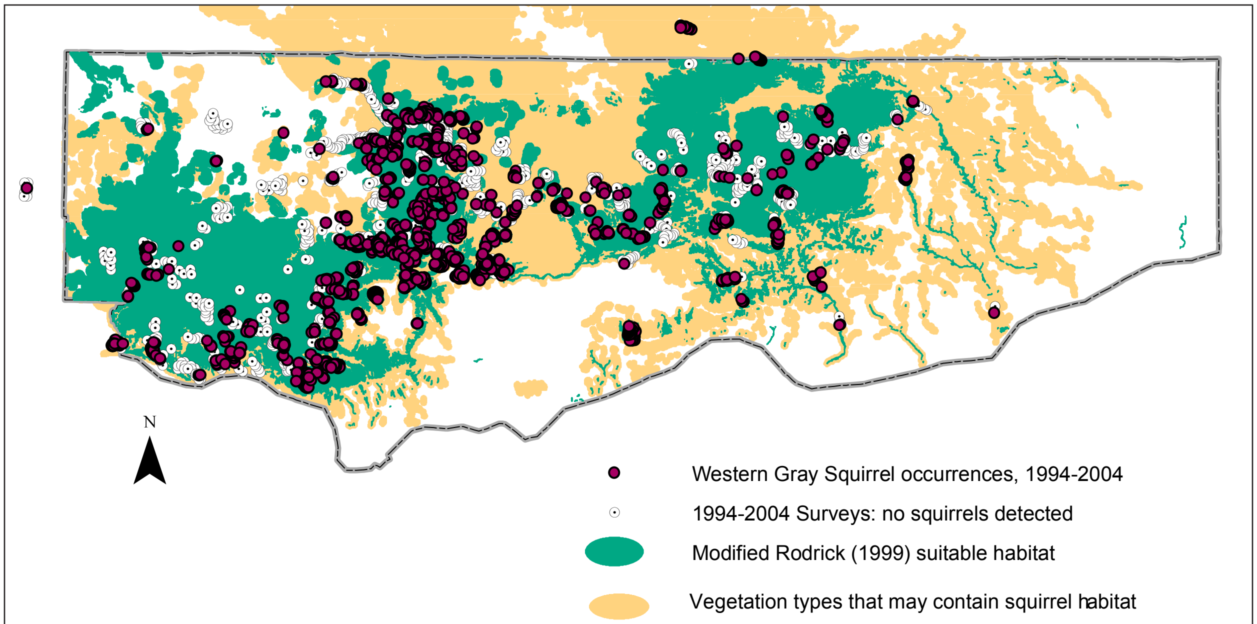
[a]Minimum estimate; additional surveys occurred in each case but no records are available of the time invested.
[b]No area estimate available for Yakima County.
[c]Including 19 occurrences in Skamania County and 64 in Yakima County.
[d]No area estimate available for the Stehekin Valley.
[e]No data available on the amount of habitat surveyed on the military bases in Puget Trough.
[f]Results between regions are not directly comparable because nests were not systematically recorded by most researchers in the Puget Trough due to potential confusion with eastern gray squirrels; this was not a problem for surveys in the Klickitat and Okanogan areas.

knowledge of western gray squirrel distribution in Klickitat County (Rodrick 1999). The 1994 – 96 survey effort had three objectives: (1) to complete oak woodland mapping in Klickitat, Pierce and Yakima counties; (2) to develop a suitable habitat landscape model for planning surveys; and (3) to conduct surveys of occupied habitat and suitable habitat of unknown occupancy for the presence of western gray squirrels. The suitable habitat map was developed from 1:12,000 scale aerial photos, taken between 1984 and 1990, using 3 habitat variables: forest cover type, canopy closure, and distance to water. It was primarily focused on nesting habitat. Types mapped for the suitable habitat map were mixed hardwood-conifer stands, oak-dominant and conifer dominant stands that were adjacent to each other, all with >25% canopy cover and within 0.8 km (0.5 mi) of water. The stand scale habitat characteristics were based on a western gray squirrel study in north-central Oregon (Foster 1992), directly south of Klickitat County across the Columbia River. When the pre-1994 western gray squirrel locations were plotted on the Klickitat County suitable habitat map, 95% of the locations fell within the suitable habitat polygon. This supported the use of the map for selecting areas to survey for western gray squirrels.

Survey areas in Klickitat County were selected from the suitable habitat map and previous western gray squirrel records. Year-1 surveys (1994) focused on previously occupied sites, year-2 on habitat upstream or downstream from occupied sites, and year-3 on suitable habitat in watersheds that had no known occurrence of western gray squirrels (Rodrick 1999). Surveys were conducted from August through November when foraging, food caching, and nest construction activities produce an abundance of sign (chewed cones, small holes, and green or brown branch clippings), and young-of-the-year attain their independence and move about in search of unoccupied habitat.

Previously occupied areas were surveyed by walking transects through suitable habitat. Transects were parallel to streams and extended up to 1 mile linear distance on either side of a squirrel location if the habitat appeared to be suitable. Parallel transects were walked 300 ft (90 m) apart and out to 1,000 ft (305 m) if suitable habitat extended that far from the stream. In 1995–1996, areas of habitat with unknown squirrel use were surveyed and reported by ¼ ¼ section (16 ha, 40 acre) blocks (Rodrick 1999).

Agency and industry personnel and volunteers from non-governmental organizations conducted surveys (Figure 9). Cooperators included The Nature Conservancy, the Columbia Gorge Chapter of the Audubon Society, Champion International, Inc., Boise Cascade Corporation, the Washington Department of Natural Resources, and the Yakama Nation. The 1994-96 surveys found western gray squirrels and/or signs of their presence in 22 water-



For Klickitat County, two different layers of western gray squirrel habitat are shown: the vegetation types that may contain squirrel habitat (light shading), and a finer resolution of suitable habitat (dark shading) that was developed specifically for Klickitat County survey planning. The map of suitable western grays squirrel habitat created for 1994-96 squirrel surveys (Rodrick 1999), was modified in 2002 based on new information and data layers. The revision omitted an association with water and used data from the Washington GAP analysis (Cassidy 1997) to exclude forest types with minimal amounts of ponderosa pine (Grand Fir and Subalpine Fir vegetation zones and land cover coded as mixed-seral or early-seral Douglas-fir).

Figure 9. Results of western gray squirrel surveys in Klickitat County, 1994-2004.

shed administrative units, up from 12 known previously. In limited surveys prior to 1994, squirrels had been recorded in 68 ¼ ¼ sections; after the 1994–1996 surveys, squirrels were known to occur in 476 ¼ ¼ sections, a 7-fold increase in known occupied area (Rodrick 1999).

Even though some specific historic sites were no longer occupied, all watersheds known to be occupied prior to 1994 were still occupied by western gray squirrels during 1994–1996. More limited surveys continued from 1998 through 2002 as part of research activities and in response to forest practice applications. A total of 712 western gray squirrel surveys were conducted in Klickitat County and adjacent parts of Skamania County from 1994 to 2002 (WDFW data system). In 2002–2003, 11 sites in Klickitat County that were occupied by squirrels between 1995 and 1998 were resurveyed to determine if squirrels were still present. All sites continued to be occupied, but with some changes in the number of active or total number of nests.

Western gray squirrels occur in small, scattered groups on the Yakama Reservation in Yakima County. Surveys conducted in 1995 and 1998 found squirrels and/or nests on at least 10 sites in canyons and riparian areas in the central portion of the Reservation.

Okanogan. A total of 301 occurrences (133 squirrels and 164 nests) were reported in the Okanogan from 1994-2004 (Fig. 10). Many occurred on the north shore of Lake Chelan and in southwestern Okanogan County, particularly along French Creek, McFarland Creek, Squaw Creek, Black Canyon Creek, and Alta Lake. During 1995–1996, apparently suitable western gray squirrel habitat was sampled in a total of 69 sections with positive observations in 32 sections (46%) and negative results in 37 sections (54%). Survey areas were selected based on a search image of occupied western gray squirrel habitat that typically included riparian draws with mixed hardwoods including black cottonwood, aspen, Douglas maple, mountain ash, and ponderosa pine (P. Bartels, pers. comm., *in* Rodrick 1999). The limited survey effort in 1995–1996 resulted in a 50% increase in 1/4 1/4 sections known to have western gray squirrels, including 2 new watersheds. One watershed where western gray squirrels had been found prior to 1994 was not surveyed during 1995–1996. From 1995 to 1997, 380 hours of surveys were conducted in the Methow Valley (Bartels 1995, WDFW data). Prior to 1995, no systematic surveys were conducted in the Okanogan and squirrels had been recorded in 20 sections in Okanogan County. Ninety-five nests and 41 squirrels were observed, including 3 road-killed squirrels. Interviews with residents in 1995 found that those in the upper Methow Valley believed that western gray squirrels were in decline, while residents of the lower Methow Valley thought the population had been stable over the previous 15 to 30 years (Bartels 1995).

In the fall of 2000, additional surveys were conducted in Okanogan and Chelan counties. About 80 hours were spent revisiting 8 sites in Okanogan County where 89 nests were recorded in 1995 (Bartels 2000, P. Bartels, pers. comm.). Twenty-three nests, 3 squirrels and 1 road-killed squirrel were observed. Changes in the total number of nests have been correlated with changes in squirrel numbers elsewhere, so the reduction in nests observed in the Okanogan could indicate a decline in this population. Peggy Bartels (pers. comm.) speculated that this might have resulted from a deep and extended snowpack during the severe winter of 1996–1997. However, where detailed descriptions or permanent marking of nest trees is lacking, relocating individual nests can be difficult (Vander Haegen et al. 2004). Chelan County was first surveyed in 2000, when 20 hours of field effort located 7 nests and 4 western gray squirrels, including 1 skin (Bartels

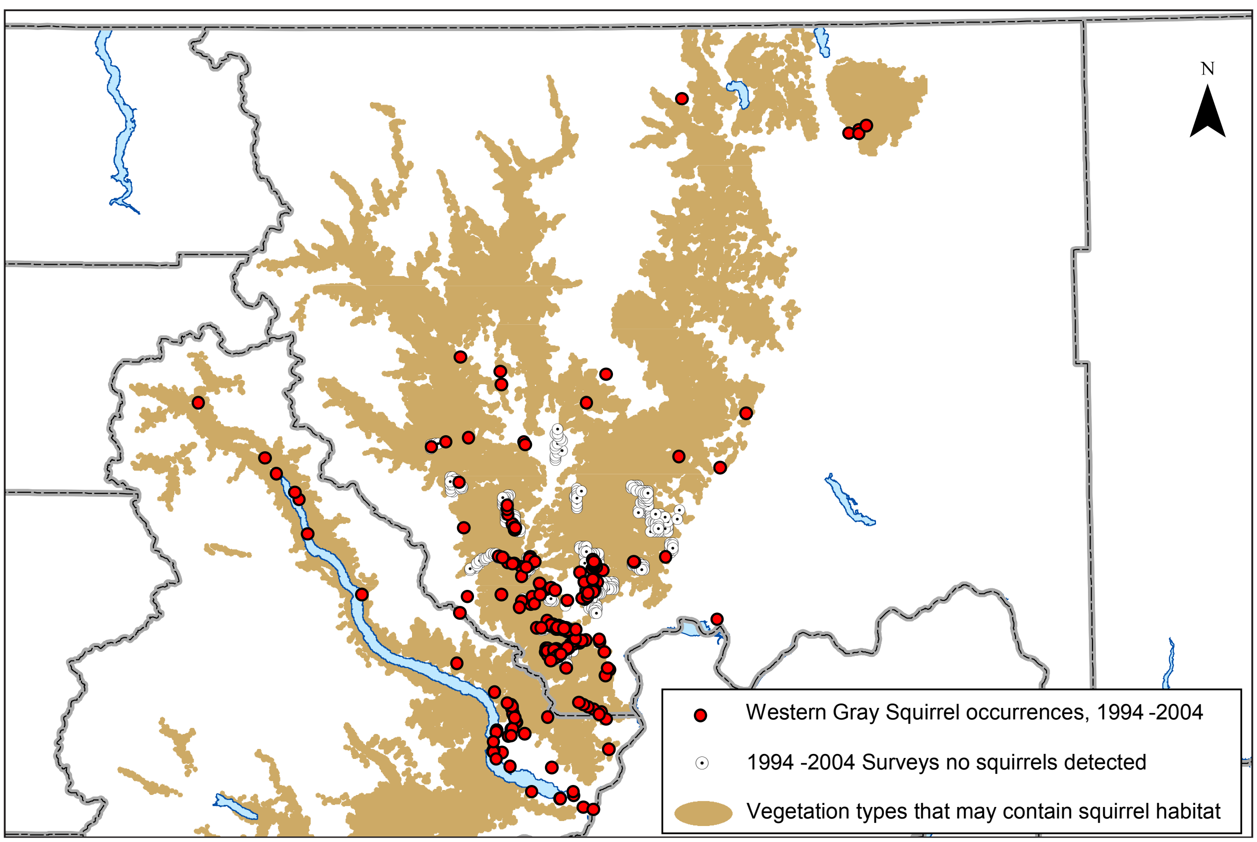


Figure 10. Results of western gray squirrel surveys in Okanogan and Chelan counties, 1994-2004

2000) which may have resulted from a raptor kill or illegal shooting (M. Vander Haegen, pers. comm.). Bartels (2000) interviewed 21 residents; several individuals noted an apparent decline in squirrels that year. Gregory (2005) recorded 65 nests and radio collared 12 squirrels in Black Canyon Creek watershed in 2003-2004. Hamer et al. (2005) conducted surveys for the National Park Service in the Stehekin Valley at the northwestern end of Lake Chelan in fall 2004. During 38 days they observed 8 squirrels and 28 nests, and obtained 4 hair samples in hair-snare traps along 11.5 km of the valley. They also obtained a report of squirrels further up the valley at Bridge Creek campground and suggested that additional surveys would expand the area known to be occupied.

Puget Trough. The Puget Trough western gray squirrel population is now centered on Fort Lewis in Pierce County (Fig. 11), but ranges north into oak-conifer communities on McChord Air Force Base (AFB) (Rolph and Houck 1996, WDFW data system). While western gray squirrels were previously found on adjacent private lands and in Thurston County, only one squirrel sighting has been reported outside the military bases since 1990 (WDFW data system). WDFW surveys in Thurston County in 1996 failed to identify sign of western gray squirrels during 36 hours of search effort (E. Rodrick, pers. comm.).

Ryan and Carey (1995b) reported 156 western gray squirrel observations during surveys conducted from 1992–1993 on 169 sites on Fort Lewis. Sites were surveyed if they were >0.1 ha (0.25 ac), had >5 oaks, were outside of developed areas or artillery impact areas, and were <500 m (547 yd) from adjacent conifers. Each stand was completely surveyed three times. Forty-six observations representing at least 38 individuals were made during 328 hours of surveys at 30 sites. Fort Lewis personnel made 110 incidental observations, from which researchers estimated an additional 43 squirrels at 14 sites. In total, Ryan and Carey (1995b) reported 81 individual western gray squirrels at 44 oak-conifer sites. This number was low relative to historic, anecdotal accounts (Bowles 1921, Couch 1926). Researchers believed the decline was linked to habitat loss and high mortality from motor vehicles (Ryan and Carey 1995b).

Survey efforts on Fort Lewis in 1998–1999 indicated a marked decline from the number of squirrels reported in 1992–1993 (Bayrakçi et al. 2001). A. Stanley (pers. comm.) initiated a behavior study on Fort Lewis, but aborted the study because she was only able to capture four squirrels and observe another six. Bayrakçi et al. (2001) located five western gray squirrels during 585 hours of foot surveys in 133 oak-conifer stands in 1998, and no squirrels during 155 hours of foot surveys and 35 hours of simulated squirrel call surveys in 1999. Additionally, western gray squirrels were not observed or captured during 8,002 trap-nights of intensive effort, 259 hours of live-trapping for flying squirrels and 108 hours of visual surveys conducted while

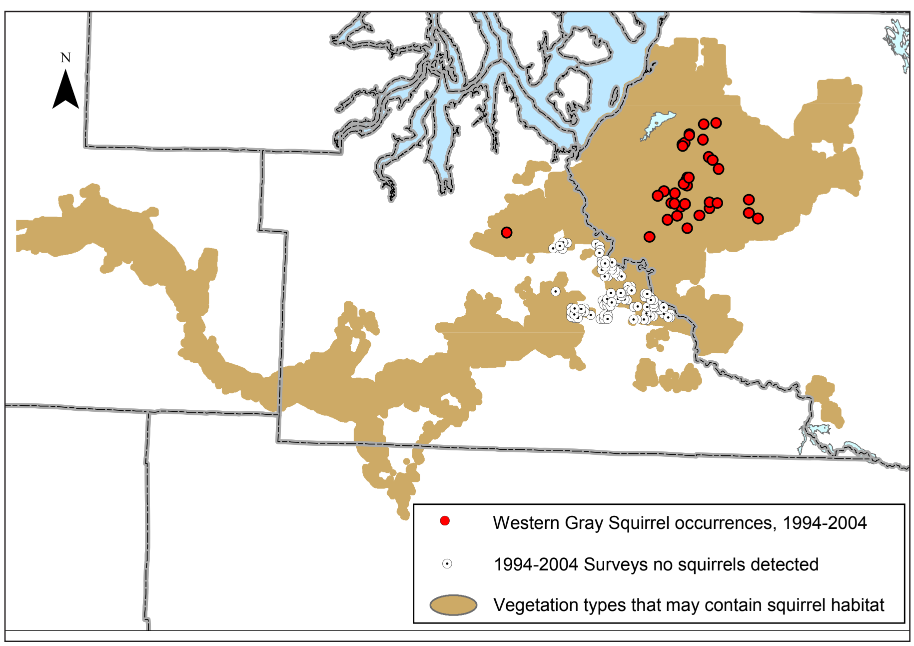


Figure 11. Results of western gray squirrel surveys in the south Puget Sound region, 1994-2004 (does not include survey sites with no detections on Fort Lewis).

trapping other small mammals. Nest locations were not recorded because of the potential for confusion with nests of eastern gray squirrels. Bait stations equipped with motion-sensitive cameras were set for 140 camera days. One western gray squirrel was photographed at a bait station in a ponderosa pine stand adjacent to oaks, bringing the total to 6 squirrels in over 4,000 hours of survey effort. Squirrels were found in less than 4% (5 of 133) of stands surveyed, suggesting that the population on Fort Lewis was dangerously low and at high risk of extinction (Bayrakçi et al. 2001). Nine western gray squirrel sightings were reported in 2002, several of which occurred in areas where habitat enhancements had taken place (D. Clouse, pers. comm.).

In February 2004, personnel from Fort Lewis and The Nature Conservancy (TNC) began monitoring western gray squirrels using hair snag tubes that collect dorsal guard hairs (Fimbel 2004b). Western gray squirrel hair can be readily distinguished from that of other squirrels by its distinct white and dark gray banding pattern. Sixty tubes were placed in oak conifer woodlands and associated ponderosa pine stands, yielding 20 samples of western gray squirrel hair in 13 different tubes. Thirty-one samples of eastern gray or Douglas' squirrel hair were captured in 21 tubes, one of which also contained western gray squirrel hair.

The number of western gray squirrels remaining on McChord AFB is unknown. TNC conducted surveys in the fall of 1993, with limited efforts in 1994 and 1995 (Rolph and Houck 1996); personnel from McChord AFB surveyed in the fall of 1994. Thirteen western gray squirrels were observed at six sites in 1993. No squirrels were observed in 1994, but two squirrels were observed in 1995 during unrelated fieldwork by TNC staff. Researchers speculated that squirrels were dispersing seasonally from Fort Lewis to McChord AFB to forage on acorns (Rolph and Houck 1996). In July 1999, a western gray squirrel was reported to be occupying a nest box erected for kestrels on McChord AFB (Bayrakçi 1999). In 2005, 2 western gray squirrels were observed in Training Area 7 on Fort Lewis, adjacent to McChord AFB; TNC is continuing detection efforts on McChord using hair snag tubes.

A very small population of western gray squirrels may exist in rural Clark County. Tracy Fleming (pers. comm.) reported that western gray squirrels were visiting a feeder near Battle Ground in 2003 and he indicated that other homeowners had photographed what appeared to be western gray squirrels in the area from Battle Ground, north to Amboy and Chelatchie. These reports may warrant surveys to determine if a population exists, and how many squirrels are present. WDFW biologists were unable to confirm a similar report near Vancouver in 2000 (J. Lewis, pers. comm.).

Statewide population estimate. There are no previous statewide population estimates for western gray squirrels in Washington. Western gray squirrels in the state are sparsely distributed, secretive and spread over large geographic areas, so it is difficult to accurately estimate their numbers. However, recent research has contributed to the understanding of home range sizes and population structure and provides some basis for calculating a hypothetical estimate. Gregory (2005:38) compared the 95% fixed kernel home range home range estimates between her Okanogan study area and those reported by Linders (2000) in Klickitat County. In Klickitat County, the home range estimate was 74 ha for males and 17 ha for females. The reported home range overlap estimates in Linders (2000) and Gregory (2005) are low (11%, 16% respectively) compared to the average total topographic overlap because they assumed that all the squirrels in their study areas were captured, and the calculation included non-adjacent individuals. If we assume that 30% of the typical home range overlaps with other squirrels (estimate based on Figs. 4, 5, *in* Linders 2000), it may, therefore, require approximately 32 ha to accommodate 1 squirrel through the non-breeding season in the Klickitat and Puget Sound regions (74 + 17 ha = 91 ha/2 = 45 – 30% overlap). Home ranges in the Okanogan are larger: 142 ha for males and 49.4 ha for females (Gregory 2005). An approximate average, assuming equal sex ratios, would be 95 ha; therefore, we assumed that 66.5 ha is needed to support an adult squirrel in the Okanogan (142 ha + 49 ha/ 2 = 95 – 30% overlap = 66.5 ha).

The adult population can be roughly estimated if the amount of occupied habitat is known. The amount of occupied habitat in each region was estimated using western gray squirrel occurrences (both nests and squirrels) recorded from 1994–2005, and applying a buffer (45 ha area for the Klickitat and Puget Sound regions; 95 ha for the Okanogan)(Table 10). The breeding populations were estimated by dividing the estimate of occupied habitat by the approximate area required to support one squirrel (32 ha for Klickitat and Puget Sound, 66.5 ha in the Okanogan).

The hypothetical population estimate is affected by several factors; some factors bias the estimate high and some bias it low. The estimate of occupied habitat was based on a cumulative number of squirrel occurrences 1994–2005. Some of the 'occupied habitat' may be currently, or was recently, vacant due to outbreaks of mange in Klickitat County and the problems experienced by the Puget Trough population. Home range data are from some of the best habitat; home ranges may be larger, with lower overlap outside of these study areas. Also, many of the surveys in Klickitat County, particularly during 1998-2005, were done in response to forest practice applications; the habitat has since been logged, with unknown impacts to the squirrels. The accuracy of the estimate of occupied habitat for the Okanogan may be affected by the limited survey work done there and fires that destroyed significant areas of habitat that was occupied in the early 1990s. Portions of the vegetation types that may contain suitable habitat in the Okanogan (Fig. 10) may be marginal or unsuitable for squirrels. Additional survey work is needed to determine the amount and occupancy of suitable habitat in the Okanogan region.

Some factors may have biased the estimate low. The estimate is for adults; the number would be higher if young of the year were included, and average home range overlap may be higher or lower than 30%. No assumption was made about the proportion of unsurveyed areas that may contain squirrels, but most of the best habitat has been surveyed. Large portions of the unsurveyed habitat in Klickitat County are Douglas-fir types; these include higher elevations around Satus Pass and the White Salmon watershed in western part of the county where detection rates were very low. The Puget Trough population seems to have declined markedly in the last 10 years, and based on recent surveys, sightings, and hair snag tubes, it may have <25 animals (D. Clouse, pers. comm.). There are no home range data from the Puget Trough.

The statewide population estimate was derived from data gathered over a 10-year period and the population may have fluctuated dramatically during that time due to mange and perhaps to variation in mast production. The true current spring statewide population remains unknown, but it is likely between 468 and 1,405 squirrels (937 $\pm$ 50%).

Table 10. Hypothetical estimate of the statewide population of adult western gray squirrels based on home range sizes and occurrences, 1994–2005.

Geographic region	Known occupied habitat (ha)	Hypothetical breeding population estimate
Puget Trough	1,349[a]	42
Okanogan	12,701[b]	190
Klickitat	22,587[a]	705
Total	36,638	937[c]

[a]Occupied habitat in Kickitat and Puget Sound was estimated by applying a 45 ha buffer to each occurrence; the Klickitat habitat estimate includes squirrel occurrences in Yakima and Skamania counties.
[b]Occupied habitat in the Okanogan was estimated by applying a 95 ha buffer to all occurrences.
[c]This estimate is considered hypothetical due to wide variation in home range size and overlap, and uncertainty about the extent of squirrel occurrences in unsurveyed habitat, and the use of cumulative squirrel locations for a 10-year period.

HABITAT STATUS

Past and Present

Oregon white oak expanded its range into Washington during the late Tertiary Period (1.8 million years ago; Taylor and Boss 1975). A more recent shift toward a moister climate in the last 5,000 years favored conifers and reduced the range of oak (Hansen 1947). At the time of Euro-American settlement, oak woodlands still remained throughout the Puget Trough, south into Clark County, along the Columbia River Gorge and north into Yakima County (Lang 1961, Kertis 1986). Native Americans affected the landscape both by setting fires to clear undergrowth (Thilenius 1968), and possibly by planting acorns, thereby influencing oak woodland distribution (Taylor and Boss 1975).

Oak and conifer communities in the state have been altered significantly since the 19th century when Euro-Americans first settled in Washington. Post-settlement oak woodlands were subjected to logging, farming and conversion to other land uses. Fire suppression, grazing and removal of oak for firewood also affected the structure and quantity of these woodlands (Lang 1961, Thilenius 1968, Kertis 1986, Franklin and Dyrness 1988). In settled areas of western Washington, fire suppression permitted Douglas-fir encroachment into oak woodlands resulting in the overtopping and death of oaks from competition (Kertis 1986, Agee 1993). Fire suppression also has allowed Scot's broom and other shrubs to invade the understory and compete with seedlings. The cumulative effects of land conversion and fire suppression have caused a severe decline in oak woodlands throughout Washington (Andelman and Stock 1994, Larsen and Morgan 1998). Consequently, oak woodlands are listed as one of the highest priorities for habitat conservation by state and federal agencies (Larsen and Morgan 1998, Cassidy et al. 2001).

Ponderosa pine forests, characterized as open and park-like by early authors, have been greatly altered in structure and composition as a result of multiple and cumulative disturbance factors since European settlement; in many cases the normal processes of these ecosystems have been degraded or lost (Cooper 1960, Weaver 1961, Covington et al. 1997, Harrod et al. 1999, Fitzgerald 2005). Changes in ponderosa pine forests summarized by Covington and Moore (1994), included: 1) overstocked patches of saplings and pole-sized trees; 2) reduced tree growth and increased mortality, especially of older trees; 3) decreased decomposition rates; 4) stagnated nutrient cycles; 5) irruption of insects and diseases; 6) decreased herbaceous and shrub forage quality and quantity; 7) higher fuel loads; 8) increased vertical fuel continuity; 9) greater canopy closure and landscape homogeneity; 10) greater severity and destructive potential of wildfires; 11) decreased streamflow; 12) less wildlife habitat for species dependent on herbaceous vegetation.

Logging in both eastern and western Washington altered the structure of pine forests by removing the largest trees and eliminating the open stands of mature and old growth pine (Noss et al. 1995). Between a historic (1932-1959) and more recent (1985-1990) period, area of old and mature ponderosa pine forest declined about 58%, 28%, and 12% in the Methow, Wenatchee, and Yakima river basins, respectively (Everett et al. 1994). Along the lower Nisqually River in the south Puget Sound region, timber cutting began around 1890; by 1917, when Fort Lewis was established, most of the forests had been cut (Foster 1997). Between 1934 and 1952 the Army resumed clearcutting, so that by 1964, 90% of the forests on Fort Lewis were less than 70 years old. Most of the remaining ponderosa pine on Fort Lewis occurs in a 500-ha forest that has been degraded by past management and fire suppression that allowed invasion by Douglas-fir, Scot's broom and exotic grasses. Portions of the area were lost to the construction of roads and training areas. Pine regeneration may be inhibited by a paucity of seed; ponderosa pines on Fort Lewis are not highly likely to bear cones until 50 cm in dbh, and trees exceeding this size are uncommon (Foster 1997).

On the east slopes of the Cascade Range, settlers brought tens of thousands of sheep into the pine forests and cleared land for agriculture (Weaver 1961). Extensive over-grazing caused a shift in the understory from grasses and forbs toward woody species, which reduced the frequency and increased the severity of ground fires (Agee 1993:333-334). By 1900, millions of pine seedlings became established in mineral soils made bare by trampling and grazing. A pine butterfly (*Neophasia menapia*) epidemic defoliated trees in the Klickitat River valley in 1893–1895. The pines appeared white and streams were choked with dead butterflies; horses and men traveling through the country were completely covered with webs of the larvae (Weaver 1961). Weakened trees were prime for attack by western pine beetles (*Dendroctonus brevicomis*). Most of the larger trees died and others were harvested. As fire control became more effective, exceedingly dense stands of young trees developed in openings and abandoned fields and filled in mature stands. Higher elevations and north slopes were invaded by fir that competed with mature overstory pines, feeding the cycle of excessive fuel loading, over-stressed trees, insect attacks and stand-replacing wildfires that now threaten the existence of many ponderosa pine forests in the state (Cooper 1960, Weaver 1961, Everett et al. 2000). Modeling by Covington and Moore (1994) of ponderosa pine forest in Arizona indicated an increase of fuel load from 1 ton/ac in 1867 to >19 tons/ac in 1987. Collectively, these events greatly altered the structure and composition of these forests from that which existed in the 1800s. In addition, wildfires have destroyed large tracts of habitat in parts of Okanogan, Chelan, Klickitat and Yakima counties over the past 30 years, and likely have contributed to the loss of western gray squirrel colonies (Stream 1993, S. Van Leuven, pers. comm.). For example, the Oak Creek Wildlife Area has had 3 fires in recent years; a fire in 2002 burned 2,400 ac in the lower 2 miles of the Oak Creek Canyon near the confluence with the Tieton River that included oaks and riparian cottonwoods.

Current Ownership and Land Use

The majority of occupied habitat (65%) is located on private lands, 19% is on federal lands, and 13% is on state lands (Table 11). Each of the three regional populations of western gray squirrels in Washington faces a unique set of management conditions due to differences in ownership. Most squirrels in the Puget Trough currently exist on Fort Lewis and McChord Air Force Base, which manage their land holdings under federal guidelines. Occupied habitat in the Klickitat is owned primarily by small private landowners, large commercial timber companies,

Table 11. Ownership of occupied western gray squirrel habitat[a] in 3 regions of Washington.

	Total		Klickitat		Okanogan		Puget Trough	
Landowner	Ha	%	Ha	%	Ha	%	Ha	%
Private	23,724	65	18,158	77	6,518	51	49	4
U.S. Forest Service	4,493	12	45	0	4,447	35	0	-
WDNR	2,951	8	1,897	8	1,053	8	0	-
WDFW	1,828	5	1,789	8	40	0	0	-
Dept. of Defense	1,300	4	0	-	0	-	1,300	96
Tribes	1,240	3	1,151	5	89	1	0	-
Bureau of Land Management	892	2	492	2	400	3	0	-
National Park Service	103	0	0	-	1,030	1	0	-
U.S. Fish and Wildlife	56	0	56	0	0	-	0	-
Washington State Parks	51	0	0	-	51	0	0	-
TOTAL	36,638	100	23,588	100	12,701	100	1,349	100

[a]Based on circular buffer of western gray squirrel and nest locations of 45 ha for Klickitat and Puget Trough, 95 ha for Okanogan, 1994–2005 (excluded 2 records from Clark, 1 from Kittitas, 1 in Thurston counties, and 3 - 4 new locations reported by Hamer et al. (2005) from Chelan County).

the Yakama Nation, the Washington Department of Natural Resources (WDNR), and the Washington Department of Fish and Wildlife. In the Okanogan, major landowners are the US Forest Service (USFS) and the WDNR, although small private lands dominate important low elevation sites.

Klickitat. Most (77%) occupied western gray squirrel habitat in the Klickitat region is privately owned, primarily by large timber companies (Table 11). The timber companies, along with numerous small landowners, harvest trees at irregular, market-driven intervals. WDNR (8%) and WDFW (8%) are the largest government landowners of occupied western gray squirrel habitat in Klickitat County. Approximately 8% of the occupied habitat in the Klickitat region would be classified as Conservation Status 1 or 2 (Cassidy et al. 2001); most is in WDFW's Klickitat Wildlife Area. The Oak Creek WLA in Yakima County contains some unoccupied suitable habitat. Conservation Status 1 lands are those maintained primarily in a natural state like National Parks and Wilderness Areas; status 2 lands are maintained mostly in a natural state but with some extractive use, such as national wildlife refuges and state wildlife areas (Cassidy et al. 2001). Although technically wildlife areas would be Conservation Status 1 or 2, the timber rights on most of the Oak Creek Wildlife Area are owned by a timber company, so WDFW has had limited ability to improve habitat values for western gray squirrels.

Okanogan. Most occupied western gray squirrel habitat in the Okanogan is in private (51%) and U.S. Forest Service (35%) ownership, followed by WDNR (8%) and BLM (3%). A vertical gradient of ownership exists: the lowlands that contain most of the riparian areas are in private ownership and the higher elevation sites are in federal ownership. Although some residents value the squirrels and feed them each winter, private lands are at risk from development and incompatible timber cutting. The Forest Service, the primary federal landowner in the Okanogan, has recently adopted a "dry forest strategy" for managing sites in the ponderosa pine zone (USFS 2000). The objective of this effort is to maintain, protect, and enhance the health of dry forest environments while reducing the risk of catastrophic wildfire through fuel treatments. This strategy could benefit western gray squirrels over time by increasing the production of pine seed, but the details of implementation are still being developed (Harrod et al. 2007a,b), and the potential short-term impacts to western gray squirrels are unknown. Short-term risks could include displacement of animals, reduction of seed supplies and hypogeous fungi, and other indirect effects related to the scale and location of implementation. A small part of the habitat on Forest Service lands is in wilderness area.

Four WDFW wildlife areas in the Okanogan region (Entiat, Chelan Butte, Sinlahekin, L.T. Murray) contain small amounts of occupied squirrel habitat and/or unoccupied habitat that may be suitable. The L.T. Murray Wildlife Area on the east slope of the Cascades in Kittitas County contains large areas of vegetation types that may contain suitable habitat and a single possible western gray squirrel nest was reported there in 2000. Management strategies for these wildlife areas include restoring ponderosa pine forest through thinning and prescribed burns. Currently, some of the habitat is in poor condition as a result of previous stand-replacing wildfires, which have reduced large areas to grassland or shrubland with small trees (M. Linders, pers. obs.). The WDFW is revising the wildlife area management plans; draft plans are available on the internet at: http://wdfw.wa.gov/lands/wildlife_areas/management_plans/index.htm.

Puget Trough. Approximately 96% of the occupied habitat in the Puget Trough occurs on Department of Defense lands and the remaining 4% is in private ownership (Table 11). Fort Lewis owns and manages a total of 22,160 ha (54,757 ac) of wooded land, of which 65% is dominated by Douglas-fir, approximately 1,400 ha (3,459 ac) is oak woodland and 775 ha (1,915 ac) is ponderosa pine woodland (Foster 1997, Bayrakçi 1999). Possible habitat outside Fort Lewis includes about 4,250 ha (10,500 ac) of oak woodland amid urban and suburban landscapes (Ryan and Carey 1995a), though most of this is probably not suitable for western gray squirrels due to small patch size, the density of roads, development, and the shortage of large oaks and conifers. The oak woodland is a mixture of public and private ownership, with some present in

WDFW's Scatter Creek Wildlife Area and some in the Black River-Mima Prairie Glacial Heritage Preserve owned by Thurston County.

Historically, frequent fires in oak-conifer sites produced stands composed primarily of mature trees (Agee 1993, Hanna and Dunn 1997). Scot's broom (*Cytisus scoparius*) is an invasive exotic shrub prominent in the Puget Trough that degrades habitat quality for western gray squirrels (Ryan and Carey 1995b). Suppression of fires since European settlement has allowed the encroachment of Douglas-fir into oak savannah and prairie areas and reduced the extent of pine forests, particularly around Fort Lewis. Encroachment by Douglas-fir and Scot's broom has also resulted in high tree density which inhibits seed production, weakens trees, reduces habitat diversity and reduces the number of healthy, mast-producing oaks and pines (Foster 1997, Peter and Harrington 2002, 2004). Western gray squirrel habitat can be highly varied in structural complexity and plant species composition, but many of the Fort Lewis oak stands contain few mast-producing tree species other than oak (Ryan and Carey 1995b). In addition, ground-truthing has found that many of the stands identified as containing oaks on maps of Fort Lewis actually contain few oak trees, suggesting that many of the communities identified as "oak-conifer" may provide poor habitat for the western gray squirrel (Bayrakçi 1999).

Forests on Fort Lewis are managed for a variety of uses that include protection of wildlife habitat as well as troop training. Much of the area is designated by the U.S. Fish and Wildlife Service as critical habitat for the spotted owl, and consequently, "production" forests are primarily managed with the objective of promoting late-successional forest (Foster 1997). A Forest Management Strategy has been developed for Fort Lewis; the goals include maintaining and restoring native biological diversity and unique habitats that include ponderosa pine and Oregon white oak plant communities, among others (DOD 2001). Fort Lewis is the first specific U.S. federal ownership to be certified by the Forest Stewardship Council for practicing sustainable forestry (DOD 2001). Current management practices are specifically designed to improve habitat conditions for western gray squirrels by releasing oaks, and reducing understory competition to improve acorn yields and lower risk of predation. Timber sales are also timed to avoid impacts to squirrels during the breeding season.

The efforts on Fort Lewis have been unsuccessful in maintaining western gray squirrel population levels (Bayrakçi 1999), but Fort Lewis personnel continue their proactive approach. As part of an ongoing commitment to sustainability, outlined in *Sustainability Implementation Plan for FY03-07* (DOA 2003), Fort Lewis will work to recover all federally listed and candidate species by 2025 and work to attain healthy, resilient Fort Lewis and regional lands that support ecosystem and other values (DOA 2003). As part of these efforts, two plans have been drafted that address oak habitat restoration and western gray squirrel management. The oak plan, *A Management Strategy for Oak Woodlands of Fort Lewis*, *Washington* (GBA Forestry 2002), is a guide to management of oak ecotones for the benefit of western gray squirrels and other oak-associates. In addition, *Strategies for enhancing western gray squirrels on Fort Lewis* (Fimbel 2004a), identifies threats to western gray squirrels and offers means of reducing or eliminating these threats.

No comprehensive plan currently exists specifically for management or restoration of western gray squirrel habitat outside Fort Lewis. Occupied western gray squirrel habitat and oak woodlands off Fort Lewis in Pierce and Thurston counties would receive some protection from county critical area ordinances, but might still end up degraded and isolated. Oak trees and woodlands are considered a "Habitat of Local Importance" in Pierce County; oak woodland and occupied squirrel habitat would be considered high priority for open space protection, acquisition, or tax relief (Pierce County Comprehensive Plan, Title 19D; County Code Title 18E).

CONSERVATION STATUS

Federal

The U.S. Fish and Wildlife Service conducted a status review of the Washington population of western gray squirrels in response to a petition received in 2000 to list the population under the Endangered Species Act. In the 12-month finding, the Service concluded that the Washington population did not represent a distinct population segment and therefore was not a listable entity, and that the population did not constitute a significant portion of the subspecies or its range (USFWS 2003). In September 2004, the U S. Fish and Wildlife Service issued a 90-day finding on a petition letter that was filed in response to the 2002 90-day finding. The Service stated that there was not substantial information either in the petition or in their files to list the Washington population, the species, or any subspecies of western gray squirrel (USFWS 2004). They recognize the western gray squirrel as a "species of concern" in the Western Washington Ecoregion. The U.S. Forest Service recognizes the western gray squirrel as "sensitive" and has identified it as a "management indicator species" for oak-pine communities in the Columbia River Gorge National Scenic Area, and in the Mt. Hood National Forest in Oregon. It is not listed as a sensitive species or management indicator species in the Okanogan-Wenatchee National Forest, or other national forests in Washington. In its Sustainability Plan (DOA 2003), Fort Lewis has committed to help recover state-listed species in the south Puget Sound region.

California and Oregon

The western gray squirrel is classified as a small game mammal in California (CDFG 2000) and Oregon. Hunting is closed in the southern third of California, but the California Department of Fish and Game is currently considering whether to open this area (T. Blankinship, pers. comm.). The western gray squirrel is included on the Oregon Department of Fish and Wildlife Sensitive Species List with an "undetermined" status, due to the potential for severe population declines (ODFW 1997); however it is still legally hunted in Oregon.

Washington

The western gray squirrel has been recognized as uncommon to rare in Washington for many years (Appendix D). In 1926, the western gray squirrel was classified as a game animal, with hunting seasons managed at the county level. From 1933 to 1954, the Washington Department of Game regulated squirrel hunting; a single hunting season for both "gray and black squirrels" existed, with timing and location variable from year to year (Appendix C.). While the season included both western gray and Douglas' squirrels, some years the season was only open in a subset of counties (e.g. Pierce, Thurston, and Klickitat Counties in 1931–1934) suggesting that gray squirrels, which are much larger than Douglas' ("black") squirrels, were the primary interest of this season. After 1954, squirrels were no longer listed in the hunting pamphlets, and they became a protected species. In 1980, the western gray squirrel was placed on the Washington Department of Game (now the WDFW) species of concern list.

In 1993, the Washington Fish and Wildlife Commission designated the western gray squirrel a state threatened species (WAC 232-12-011) based on a WDFW status report (WDW 1993). A state threatened species is defined as "any wildlife species native to the state of Washington that is likely to become an endangered species within the foreseeable future throughout a significant portion of its range within the state without cooperative management or removal of threats" (WAC 232-12-297, Section 2.5).

MANAGEMENT ACTIVITIES

Management activities for western gray squirrels in Washington have been conducted by WDFW and other agencies and private entities. Activities have included surveys in Klickitat, Okanogan, Chelan, Thurston, and Pierce counties, and by the Yakama Indian Nation. Research has included cooperation with private and public landowners. Fort Lewis, TNC, and the U.S. Forest Service PNW Research Lab have been involved in research, restoration, and conservation of the Puget Trough squirrel population. The National Park Service has been involved in funding surveys and research on squirrels in Chelan County. Klickitat County has provided extensive comments on recovery plan drafts and has recently sought greater involvement in recovery planning and implementation of recovery actions. Some private landowners have conducted timber harvests that carefully preserved key habitat values.

Habitat Protection and Restoration

Washington Department of Fish and Wildlife Area Habitat Biologists work with landowners, other agencies and jurisdictions, especially Klickitat County and WDNR, in efforts to protect western gray squirrel habitat values (B. Weiler, C. Dugger, pers. comm.). WDFW Priority Habitats and Species (PHS) Management Recommendations for western gray squirrel were first published in 1991 (Rodrick and Milner 1991). These provide guidance to landowners, county planners, and agency personnel for protecting western gray squirrel habitat values during logging, development, or other land use activities. The management recommendations will likely be revised in the next few years to incorporate recent research.

Habitat restoration to benefit western gray squirrels is occurring on Fort Lewis and WDFW lands. Restoration efforts have some potential to adversely impact small populations of squirrels in the short-term; however, if conducted carefully, the benefits of restoring oak and pine ecosystems likely outweigh the risks.

Fort Lewis. In 1984, Fort Lewis personnel recognized that western gray squirrel habitat was in need of enhancement. They initially erected nest boxes, but these failed to attract western gray squirrels. In 1998, the military adopted management recommendations by Ryan and Carey (1995a) that called for more research on habitat requirements for western gray squirrels and methods for habitat enhancement. Currently, researchers at the USDA Forest Service Pacific Northwest Research Station are studying seedling and tree response of Oregon white oak to canopy thinning and controlled fire on Fort Lewis (Peter and Harrington 2004). In addition, Fort Lewis and The Nature Conservancy (TNC) have also begun restoration work in both the oak and pine communities to reduce fire hazard, restore native plant communities and enable troops to move more easily through the understory (Foster 1997, Bayrakçi 1999). These treatments involve mowing, under-burning and the removal of substantial amounts of Douglas-fir and Scot's broom (P. Dunn, pers. comm.); efforts to document habitat response to these treatments began in the fall of 2004. There is also an interest in documenting responses of both eastern and western gray squirrels to the treatments (D. Grosboll, pers. comm.). In cooperation with TNC, Fort Lewis personnel are identifying stands for oak restoration.

WDFW Wildlife Areas. Oak habitat restoration has been conducted on Scatter Creek Wildlife Area in Thurston County. This included creating snags out of firs that were encroaching on oaks and removal of extensive areas of Scot's broom in prairie and oak habitat. Habitat improvement on the Klickitat Wildlife Area has included a prescribed burn that was primarily aimed at improving habitat for mule deer. The burn may have improved habitat somewhat for squirrels as well, but conditions were not ideal during the burn; it was not as effective for clearing underbrush as was hoped. A set of exclosures was recently established to investigate the potential impact of livestock and deer browsing on oak regeneration. Strategies listed in the draft Klickitat Wildlife Area management plan include thinning and prescribed burning to improve habitat quality for deer, and monitoring the thinned and burned areas for western gray squirrel use (Ellenburg and Dobler 2006). Specific plans for prescribed burns and thinning operations on the Klickitat Wildlife Area are being developed. The strategies in the draft management plan for Oak Creek Wildlife Area include acquiring the perpetual timbers rights, restoring mature dry forest conditions, and improving habitat for wildlife diversity (McGowan and Stream 2006).

Surveys

WDFW initiated intensive western gray squirrel surveys in Washington in 1994, as discussed in detail under Population Status. Intensive field surveys were conducted in Klickitat County from 1994 to 1996 by public agencies, the private sector and the Yakama Nation (Rodrick 1999) and subsequent surveys were conducted from 1998–2004. Currently, agency and industry personnel conduct surveys on potential and historically occupied sites proposed for forest practices activity. Survey efforts in the Okanogan were reported in Bartels (1995 and 2000) and Rodrick (1999). Hamer et al. (2005) conducted surveys at Stehekin, on the north end of Lake Chelan in fall 2004. Results of surveys conducted on McChord AFB by TNC were reported by Rolph and Houck (1996). Survey results from Fort Lewis were reported by Ryan and Carey (1995b) and Bayrakçi et al. (2001). Monitoring of the squirrel population on Fort Lewis began in February 2004, when hair snag tubes were placed on the ground and in trees in oak-conifer and pine woodlands (Fimbel 2004b).

Research

Ecology. Several studies on the ecology of the western gray squirrel have been conducted in Washington. Barnum (1975) collected data on home range, habitat requirements, diurnal activity patterns and behavior by observing eight color-tagged squirrels in a canyon east of Goldendale in Klickitat County. A survey of historic habitats in the Puget Trough and Klickitat County was conducted in 1985–1986 using baited track plates (Rodrick 1986).

Two studies were conducted on the western gray squirrel population at Fort Lewis to describe distribution, abundance, habitat, behavior and limiting factors and to provide recommendations for future management (Ryan and Carey 1995a,b, Bayrakçi 1999, Bayrakçi et al. 2001). Bayrakçi's (1999, 2001) work included a comparison of survey effort between studies and documented a population decline.

In 1998–1999, a study on home range and habitat use by western gray squirrels was conducted on the Klickitat Wildlife Area in Klickitat County (Linders 2000, Linders et al. 2004). Data collected from 25 radio-collared squirrels were used to determine home ranges, movement patterns, and habitat preferences of this species on the Klickitat Wildlife Area.

In the fall of 2000, WDFW began a second phase of the squirrel study on the Klickitat Wildlife Area. This area was chosen for study because it appears to host the highest density of squirrels found on public land in Washington. From 2000–2004, 149 individual squirrels were captured and ear-tagged or equipped with radio transmitters. Radio-tracked squirrels were used to evaluate reproductive success, home range, movement, juvenile dispersal and survivorship. Mark-recapture methods on a 78–ha grid were used to estimate population densities (Vander Haegen et al. 2005).

Limited research evaluating the effects of timber management on western gray squirrels in Klickitat County was conducted by WDFW in 1999–2000 (Vander Haegen et al. 2004). The study was inconclusive, in part because a widespread increase in nests on both harvested and control sites appeared to have swamped the results. Additionally, the relationship between numbers of nests and squirrel populations has not been established. One conclusion was that compliance with the harvest guidelines was an important factor affecting continued presence of squirrel nests. The authors emphasized the need for additional research on the effect of timber harvest on squirrels.

In spring 2003, a cooperative western gray squirrel study by WDFW, the University of Washington and the U.S. Forest Service was initiated in Okanogan County. Gregory (2005) radio-tracked 12 western gray squirrels to determine home range, movements and nest site selection parameters in the Okanogan.

The USDA Forest Service Pacific Northwest Research Station, in cooperation with the Fort Lewis Forestry Program, initiated a study of the response of Oregon white oak to release from overtopping by Douglas-fir and to different methods of planting oaks (Devine and Harrington 2004). Preliminary results suggested that full release of oaks rather than an incremental release may be more beneficial for oaks in the Puget Sound region (Devine and

Harrington 2004). In addition, the PNW Research Station has been conducting research on the factors affecting acorn production (Peter and Harrington 2002, 2004). These studies may help in improving methods of habitat enhancement for western gray squirrels.

An intensive study of western gray squirrel ecology on Fort Lewis by WDFW and a University of Washington graduate student was intiated in 2007; objectives include investigating productivity, dispersal, survival, and relationships to eastern gray squirrels.

Genetics. Research on western gray squirrel genetics is limited to three recent studies, which looked at genetic relatedness among squirrel populations in Washington and between squirrels in Washington and in other states. Parametrix (1999) conducted a study to determine the degree of genetic relatedness between three Washington and two Oregon populations of squirrels. Based on sampling mitochondrial DNA from a total of 6–10 squirrels, Parametrix (1999) found little evidence for genetic divergence between these populations.

In 2003, the Washington Department of Fish and Wildlife initiated a study of the levels of genetic diversity and differentiation within and among populations of western gray squirrels in Washington, Oregon, and California using microsatellite DNA analysis (Warheit 2003). Samples from 128 squirrels included tissue from museum collections, museum skins, ear punches from live-trapped squirrels, and road-killed squirrels. Genetic diversity refers to the total number of alleles present in a population, while genetic differentiation refers to the frequency of genotypes in a population. Genes may have 1 or more pairs of alleles, which provide the genetic coding for physical traits. Populations in Washington displayed significantly lower levels of genetic diversity based on the number of alleles present. Observed and expected heterozygosities in Washington were reported to be half those in Oregon, even though the Washington sample size was >4 times higher (Warheit 2003). This means that more individuals had matching pairs of alleles rather than two different alleles at the same gene locus. The study suggests significant genetic differentiation between the populations in Washington and those south of the Columbia River, based on the distribution of genotypes in each population (Warheit 2003). There are significant genetic differences among the three Washington populations but they are more closely related to each other than to any population south of the Columbia River. Washington populations seem to be functioning as three separate, isolated populations. The results are in contrast to those reported by Parametrix (1999); however, Ken Warheit (pers. comm.) suggested this may be explained by the small sample size in the Parametrix study.

Researchers at the University of Washington's Burke Museum used mitochondrial DNA control region sequencing to determine the level of relatedness between western gray squirrels from Washington and those from Oregon and California. Preliminary results revealed only three haplotypes (groups of closely-related genes) from Washington squirrels (n = 40), whereas 14 haplotypes were identified from Oregon and California squirrels (n = 27 combined) (Warheit 2003). No haplotype was shared across the Columbia River. Haplotypic differentiation was highly significant between Washington, Oregon, and California. These populations seem to have diverged from one another a long time ago. Calculating divergence dates was somewhat problematic due to a lack of comparable data for closely related species, but divergence dates between each pair of populations were estimated to be about 12,000 to 126,000 years ago based on rates used for mice and rats (Warheit 2003).

Outreach and Education

WDFW produced a pamphlet to aid in the identification of western gray squirrels entitled, *The Western Gray Squirrel and Other Squirrels in Washington*. The pamphlet contains photos and descriptive information for seven species of native and introduced tree squirrels and the California ground squirrel to help minimize incidental shooting mortality due to mistaken identity and to facilitate more accurate sighting data. The pamphlet was first produced in the early 1990s and was revised in 2003; a web version is available at: http://wdfw.wa.gov/wlm/diversty/soc/wgraysquirrels/. In 2003, WDFW sponsored an Oregon White Oak conference that was attended by 150 people (B. Weiler, pers. comm.).

FACTORS THAT MAY AFFECT CONTINUED EXISTENCE

Adequacy of Existing Regulatory Mechanisms

Regulations generally provide little protection for suitable habitat that is temporarily not occupied by western gray squirrels. Populations of western gray squirrels can fluctuate dramatically and habitat may be vacant for several years until it is recolonized. Demonstrating squirrel occupancy often relies on finding nests, but some oak stands might provide critical foraging area and maternal den sites but the only visible nests are built in nearby conifer stands (S. Van Leuven, pers. comm.). Also, telemetry has revealed that many stick nests are not detected during squirrel surveys. In Klickitat County, neither WDNR, the county, nor the Columbia Gorge Commission, has been willing to protect habitat that appears suitable, but is not demonstrably occupied by squirrels (B. Weiller, pers. comm.).

Federal. The western gray squirrel is recognized as a "species of concern" by the U.S. Fish and Wildlife Service, and a "sensitive species" and "management indicator species" by the U.S. Forest Service; however, these classifications provide no species protection and little protection to western gray squirrel habitat. Such species may receive some consideration in federal plans, but there is no requirement to avoid or minimize direct or indirect impacts to the species' habitat.

The Columbia River Gorge National Scenic Area (NSA) includes areas of western gray squirrel habitat in southwestern Klickitat County, and southern Skamania and Clark counties. The NSA is jointly administered by the Columbia River Gorge Commission and the U. S. Forest Service. Conservation measures are in place that protect sites occupied by state-listed species. This protects confirmed western gray squirrel nests and requires WDFW-approved plans for development or logging where western gray squirrels are located.

Department of Defense funding for management of individual species is prioritized based on potential impacts to training and/or potential violations of the Endangered Species Act. Policy for the management of natural resources on military installations is contained in Army Regulation 200-3 and the SIKES Act (D. Clouse, pers. comm.). Policy or guidelines for the management of specific species, including the western gray squirrel, is contained in the *Fort Lewis Fish and Wildlife Management Plan* (DOA 1998) and *Integrated Natural Resources Management Plan* (DOA 2000). Although no training restrictions are in place within areas occupied by western gray squirrels, Fort Lewis Range Regulations prohibit the intentional harassment of all wildlife species and Fort Lewis has been a proactive leader in western gray squirrel conservation.

Habitat conservation plans (HCPs) are agreements between a landowner and the U.S. Fish and Wildlife Service designed to provide habitat protection for wildlife species of concern in exchange for the freedom to conduct management actions (e.g. harvesting trees) as agreed to in the plan (USFWS 1999). The plan results in an incidental take permit, which allows the loss of a certain number of individuals, should a federal listed species be harmed in the process of carrying out the designated management actions (USFWS 1999). A Washington Department of Natural Resources (DNR) HCP protects some aspects of oak woodland habitat (e.g., trees >20 inches in diameter and maintenance of 25–50% canopy cover) in west-side planning units, but no special protections are provided for western gray squirrels. Neither oak woodlands nor western gray squirrels east of the Cascade Mountains receive special protection under the DNR HCP.

State. The western gray squirrel is classified as a threatened species by the Washington Fish and Wildlife Commission (WAC 232-12-011). It is protected from malicious killing and malicious destruction of nests under RCW 77.15.130. State laws regulating timber harvest activities on state and private land do not provide specific protection for western gray squirrel habitat. New state "Forest and Fish" Forest Practice Rules (FFR; WAC 222) are designed to protect habitat for fish and some stream amphibians, and may provide limited benefit to western gray squirrels, specifically where habitat occurs within a stream buffer. Forest Practice Critical Habitat Rules (WAC 222-16-080 and 222-10-040) under the State Forest Practices Act (RCW 76.09) apply to forest practices on state and private land that may impact state and federal listed species. The Forest Practices Board may consider adopting a critical habitat rule for species following listing. After state listing of the western gray squirrel in 1993, the board considered options for a critical habitat rule in 1996, but decided not to adopt a rule for the western gray squirrel (WDNR 1996). Instead, a set of guidelines (Appendix E) was developed for forest practices occurring in western gray squirrel habitat on state and private land. The key provisions of the harvest guidelines are maintaining a 50 ft. no-cut buffer and at least 50% canopy closure within 350 ft of nest trees. As practiced in Klickitat County, the guidelines have been somewhat flexible, for example, allowing occasional entry into the buffer. The intent was to give the agencies and landowner flexibility to tailor a plan that protected essential habitat components based on site-specific conditions (WDNR 1996). When a forest practice is proposed in an area identified as squirrel habitat, but not known to contain squirrel nests, the DNR forester will add the following language to the application:

> "this proposal contains components of western gray squirrel habitat. Whenever possible, clumps of Oregon oak should be protected during falling and skidding operations from unnecessary damage. Should a squirrel and/or nest be found, the nest tree shall be protected and notify [WDFW]." (T. Bates, pers. comm.)

When a forest practice is proposed in an occupied site, the WDFW Area Habitat Biologist develops a harvest plan based on the guidelines. DNR is notified if the landowner agrees to conduct operations consistent with the plan. The guidelines are considered voluntary because they are enforceable only to the extent that DNR places specific conditions on the Forest Practices Application. Generally, DNR can condition applications to prevent "material damage" if an agreement is not reached and WDFW sends a letter to DNR stating that the harvest as proposed is likely to harm western gray squirrels.

Habitat and complete squirrel occurrence maps are not available for the Okanogan region, so some forest practices affect squirrels and habitat without input from WDFW. Where squirrels are known to occur, the state guidelines are used as a starting point for negotiating a squirrel protection plan for the forest practice (L. Hoffman, pers. comm.).

A preliminary study of the effectiveness of the western gray squirrel nest protection guidelines at protecting nests was conducted in Klickitat County in 1999–2000. The study included 20 sites, each of which had >10 active nests in original surveys. Ten of the sites were logged and 10 were unharvested control sites. Some of the results were unclear or appear contradictary. The number of nests found during re-surveys was higher for both harvested (47%) and control (46%) sites, possibly reflecting both a population change in the area and more thorough search effort in resurveys (Vander Haegen et al. 2004). There was no significant difference between the increase in total nest numbers on harvest sites vs. control sites, but the increase in active nests was significantly greater on harvest sites vs. control sites. The magnitude and direction of change in nest numbers varied greatly among individual sites, both for harvest and control sites.

Nest protection and consistency with the guidelines were also evaluated. Harvest units were rated on a scale of 1 to 3 based on overall percent of nest trees that were protected according to the guidelines (1= ≥90%, 2=75-89%, 3= <75%). Nests receiving "good" protection (50-ft no cut buffer and retention of canopy cover in the surrounding area) were more likely to have active nests than sites that received "poor" protection. Six of nine harvest units earned a '3' (poorest) rating for nest protection, with an average rating of 43% (range 14-67%). Operators sometimes failed to follow the guidelines specified in forest practice permits by removing large pines in close proximity to the nest, damaging the nest tree, or thinning of young trees in the no cut buffer (Vander Haegen et al. 2004). However, a consequence of the scoring was that one site was rated "poor" because the operator freely entered the 50-ft buffers to remove small saplings, although this likely improved the habitat for squirrels (S. Van Leuven, pers. comm.). Of the 5 harvest units where the active nests declined between surveys, 4 earned a rating of '3' and the fifth earned a '2.' However, 2 units that earned a rating of '3' had an increase in active nests. Both sites that earned a '1' (best) showed no decline in the number of active nests; one of these was helicopter logged. Where the 50-ft nest buffer was entered during harvest, the nest was half as likely to remain active as where the buffer was not disturbed (Vander Haegen et al. 2004).

Sue Van Leuven (pers. comm.), a study co-author who surveyed and re-visited many of the sites, noted that the response of squirrels to timber harvest seemed to depend on the quality of the habitat prior to harvest. Squirrels in high quality sites fared better post-harvest, while on one or more marginal sites, the squirrels vacated the site even though compliance with the guidelines was good. This included one unit where compliance was good, but an adjacent pine stand was clear-cut, apparently eliminating most of the food for the squirrels. These observations support the idea that management at a landscape scale where possible may be more successful than focusing solely on nest sites.

The authors cautioned that the study was preliminary; counting nests provides an index of squirrel abundance, but does not provide information about the age or reproductive status of the individuals on the site. They stressed the need for an experimental study that evaluated squirrel demography on the site as a function of harvest. Linders (2000) noted that there may be potential for moderating harvest guidelines around nests used for resting vs. primary nests used by reproductive adults; this would require developing criteria for identifying the different nest types.

Counties. County and city regulations can provide important protections for the habitat of listed species. Under Washington's Growth Management Act, counties and cities are required to develop critical area ordinances that identify fish and wildlife habitat conservation areas and use the best available science to regulate development that would impact those areas (RCW 36.70A.050 and 36.70A.172). Counties vary in critical area definitions and implementation, but generally development proposals that would impact the habitat of a listed species can be conditioned to avoid, minimize and mitigate impacts. Where projects involve the cutting of large trees, particularly oaks, effective mitigation is difficult because of the species' slow growth and the long time needed before trees produce acorns in significant numbers and develop cavities suitable for natal squirrel nest sites.

Pierce, Thurston, Okanogan, Chelan, and Klickitat counties have critical area ordinances that apply where western gray squirrels are known to occur. Klickitat County's critical areas ordinance defines the habitat of federal or state-listed species as Critical Wildlife Habitat Conservation Areas and requires that land development activities in these areas must avoid, minimize or mitigate impacts to the wildlife habitat values. However, Klickitat County does not have a grading ordinance, so construction of driveways and roads is not reviewed for potential impacts to western grays squirrels (B. Weiller, pers. comm.).

The Pierce County Critical Area Ordinance (Title 18E.40) regulates development activities that impact occupied western gray squirrel habitat as well as Oregon white oak trees and woodlands. Oak woodlands are designated as a "Habitat of Local Importance." When a proposed regulated activity is located within this habitat, the county requires the submittal of a fish and wildlife application and habitat assessment. The proposal must avoid and minimize impacts to the habitat as much as possible. Where encroachment on the regulated habitat cannot be avoided, mitigation must achieve "equivalent or greater biological function" to that lost by the project (Title 18E.40.050).

Thurston County includes habitat of western gray squirrels as "Important Habitats and Species" in its critical areas ordinance; woodland that contains ≥20% oak is regulated, but it must be >5 ac in extent. At time of publication, Thurston County was in the process of updating its ordinance.

Okanogan County identifies the habitat of state threatened and endangered species as critical areas; however, the county does not have a clearing and grading ordinance. Therefore the habitat may have been destroyed before a building permit is sought. Okanogan County also does not employ staff to enforce critical area ordinances, so western gray squirrel habitat may not be effectively protected. The county is not required to update its critical area ordinance until 2010.

Yakima County protects only state listed species that are associated with wetlands, and the county has initiated a non-regulatory, incentive-based program for natural resource protection. At the time of publication, Yakima was in the process of updating its critical areas ordinance. Chelan County identifies state threatened and endangered species for protection in its critical area ordinances, which would help protect occupied western gray squirrel habitat. Yakima and Chelan counties are required to update their critical area ordinances by December 2007.

Habitat Destruction and Degradation

Oak-conifer communities and late-successional forests have changed dramatically in the past century (Detling 1968, Taylor and Boss 1975, Kertis 1986, Ruggiero et al. 1991, Agee 1993), and these habitats continue to decline in extent (Andelman and Stock 1994, WDNR 1996). Threats to habitats used by western gray squirrels include development, road building, logging, wildfire, and changes resulting from fire exclusion.

Development. Development patterns on the east slope of the Cascade Mountains may cause fragmentation and decline of western gray squirrel populations. Ecological assessments in the Okanogan found that riparian vegetation was fragmented and reduced in extent, with significant declines of cottonwood, aspen and other riparian-associated species (USDA and USDI 1996). In these areas, mountainous terrain concentrates building, farming, roads, and railroads into narrow riparian corridors and floodplains. Many western gray squirrel nests in the Okanogan and Klickitat are located in narrow riparian areas on private lands. Development in these areas effectively reduces habitat quantity and quality and increases fragmentation and exposure to mortality factors like predation and automobiles. In Klickitat County, large tracts of pine and oak woodland are being subdivided into 5, 10, and 20-acre parcels (C. Dugger, B. Weiler, pers. comm.). Although low density development probably can be compatible with western gray squirrel occupancy, land use activities associated with these subdivisions typically include land clearing and home and outbuilding construction that further fragments and degrades habitat.

Urban development poses a significant threat to the last remaining western gray squirrel habitat in the Puget Trough (Kessler 1990). Although significant destruction and fragmentation of oak woodlands has been ongoing since the early 1950s (Rodrick 1986), the conversion rate of oak–conifer communities into housing developments is increasing. Kessler (1990) estimated that there were about 10,200 ac of oak woodland in Thurston County in 1990. About 7,700 ac of this is on private lands (Kessler 1990, Ryan and Carey 1995a) and either exists in a matrix of suburban development where its habitat value is severely compromised, or it is at risk of development.

Oaks are sensitive to surface disturbance such as grading and trenching because they have most of their roots within the top 2 feet of the soil surface (Ryan and Carey 1995a). These activities can compact the soil, killing roots through oxygen deprivation (Guisti 1993). Efforts to retain individual oaks after development are often unsuccessful because of disturbance to root systems or fungal diseases associated with watering (Rush 1989). Oaks that survive the development process do not appear to provide suitable western gray squirrel habitat, due in part to the squirrel's tendency to avoid humans and developed areas (Byrne 1979, WDW 1993). As human populations continue to increase in the Puget Trough, development and land clearing will further reduce remaining western gray squirrel habitat. Developments may also reduce available habitat for western gray squirrels on federal lands in the Puget Trough. A proposed southern extension of the runway on McChord AFB and an industrial park on Fort Lewis could eliminate 254 acres of oak and conifer woodlands (FHWA 2003). These military lands contain the largest tracts of publicly-owned oak woodlands in the Puget Trough region (Ryan and Carey 1995b); their destruction reduces the habitat available for western gray squirrel recovery in western Washington.

Roads. In both urban and rural areas, vehicles contribute notably to western gray squirrel mortality, especially when juveniles are dispersing (Ingles 1947, Gilman 1986, Verts and Carraway 1998, Weston 2005). With the continued expansion of human populations in the Pacific Northwest, both road density and traffic volumes can be expected to increase across the landscape; this likely translates to an increased risk of death to squirrels on roads. The cumulative impacts of roads and associated development have a significant adverse impact on populations and increase the risk of extinction. Death by motor vehicle was a significant problem for the Puget Trough western gray squirrel population in 1992-1993 when Ryan and Carey (1995b) reported that 16% (13 of 81) of the western gray squirrels they observed died on roads. Although researchers on Fort Lewis did not observe road-related mortality in 1999, this was likely a reflection of low population density rather than a decreased risk of death by road-kill (Bayrakçi 1999). Three road-killed western gray squirrels were recovered from Fort Lewis in 2001–2002, including one female, one male and one juvenile (WDFW files). Road-kill mortalities continue to occur in spite of exceedingly low population levels; at least four squirrels were killed on Fort Lewis in 2005, and at least four in 2006 (D. Clouse, pers. comm.).

In Yakima County, Gaulke and Gaulke (1984) reported that road-kill mortalities negatively impacted the western gray squirrel population. Squirrels often cross roads to access foraging sites, which can expose them to vehicles on a daily basis (M. Linders, pers. obs.). The mating behavior of male squirrels in Klickitat County caused squirrels to risk crossing a highway frequented by logging trucks. Immature squirrels may also suffer disproportionately from road-kill mortality (Gaulke and Gaulke 1984, Ryan and Carey 1995b). Two dozen western gray squirrels were known to have been killed by vehicles in Klickitat County in 2005. Significant mortalities occur on: 1) the Glenwood-Goldendale Rd., especially where it is adjacent to the Klickitat Wildlife Area; 2) State Route 142 along the Klickitat River; and 3) Lyle-Centerville Rd. between mileposts 2 and 3 (B. Weiler, pers. comm.).

Western gray squirrel road kills are common along Highway 153, south of Methow, in Okanogan County. Thirteen squirrels killed by motor vehicles were collected during WDFW survey efforts between 1995 and 2000. The majority of road kills have been located at the intersections of Highway 153 and Black Canyon Creek Road, and Highway 153 and Hurricane Canyon. R. Hagenbush, who traveled Highway 153 routinely for many years, indicated that between four and 30 road kills were noted each year (P. Bartels, pers. comm.). The actual amount of road-kill mortality may be underestimated because some squirrels are likely removed by scavengers, and humans occasionally remove road kills for taxidermy (M. Linders, pers. obs.) and fly-tying purposes (P. Bartels, pers. comm.).

Pierce County, the Washington Department of Transportation (WSDOT) and the Federal Highway Administration have proposed SR 704 (the Cross-Base Highway), a new four- to five-lane highway, across the north end of Fort Lewis and the southern portion of McChord Air Force Base (FHWA 2003). The chosen route traverses the northern part of the area supporting the Puget Trough population of western gray squirrels. If constructed, the highway will divide, fragment and eliminate significant portions of the remaining oak-woodland/conifer/wetland mosaic. It is also expected that the proposed highway would be an impediment to dispersal and colonization. Associated security fencing would likely isolate the habitat and any squirrels and eliminate the potential for western gray squirrels north of the highway, because the area would contain insufficient habitat to support a population. The construction of SR 704 would eliminate approximately 166 ac of oak/savanna habitat, isolate approximately 3500 ac, and result in some level of disturbance to approximately 700 ac of habitat (WDFW/WSDOT 2005). The final environmental impact statement (FHWA 2003) lists a total 2,323 ac of possible squirrel habitat and travel corridors affected by the project.

The Record of Decision for the proposed highway was issued by the Federal Highways Administration in August 2004; this finalized the route selection for the SR 704 project among several alternatives and was a step that is required for securing federal funding of the project (FHWA 2004). In an agreement reached between WDFW and WSDOT, impacts to oak/savannah habitat caused by the project will be offset by the acquisition, restoration and enhancement of 364 ac which will be restored to an equal level of function as that impacted by SR 704 (WDFW /WSDOT 2005). Other mitigation measures include fencing of the highway to reduce road mortality and culverts to provide small animal crossings under the roadway (FHWA 2003). Habitat restoration will improve the site's potential to support squirrels, but may require a long period of time (>40 yrs) due to the slow growth rate of oaks. As of May 2007, the habitat plan had come to an impasse because the landowner was unwilling to sell the needed land. There is also some uncertainty about whether SR 704 will be among the highway projects prioritized for funding in the current state funding package.

Logging. Logging and land clearing may degrade western gray squirrel habitat by destroying nests and potential nest sites and fragmenting the tree canopy that squirrels use for travel and escape cover, and disturbing the soil (Vander Haegen et al. 2004). Removal of the largest ponderosa pine reduces pine seed available to squirrels, a critical food source. Soil disturbance, compaction, and reduction of canopy closure during logging affects the abundance of hypogeous fungi eaten by squirrels (Pederson et al. 1987, States and Gaud 1997), and may affect the abundance of beetle larvae and forbs as well. Overall, these activities may suppress squirrel populations by decreasing the food supply, reducing quality of nest sites, increasing predation, and interfering with reproductive activities.

Most commercial logging in dry forest of the Klickitat and Okanogan regions involves partial cuts with harvests generally removing many of the large pines. Large oaks and pines are the best mast-producers and interconnected (crowns <1 m apart), conifer dominated stands of large diameter mast-producing trees are essential characteristics of good western gray squirrel habitat (Linders 2000, Gregory 2005). Clearcutting in the more mesic forest types may have increased in recent years. Mixed Douglas-fir and pine stands are sometimes clearcut and planted to Douglas-fir. Harvests that result in low canopy closure with evenly spaced trees and few or no canopy connections create conditions poorly suited for western gray squirrels. The history of logging, grazing, and fire suppression has often resulted in overstocked stands of smaller trees; remaining large trees have reduced vitality and produce less mast for squirrels and other wildlife (Peter and Harrington 2002, Krannitz and Duralia 2004). Experimental removal of Douglas-fir that over-topped oaks on Fort Lewis resulted in increased acorn production, and oaks began to rebuild their crowns (Devine and Harrington 2004). Some level of thinning harvest may improve food resources by increasing sunlight to remaining oaks and pines and increasing mast production, but the food may not be available to squirrels if canopy closure is reduced too much and trees are evenly and widely spaced rather than providing connections for arboreal travel. Harvest that removes smaller trees and leaves the large trees is not typical of commercial logging. The recovery of habitat to a condition that will support squirrels after cutting of large pines or oaks requires a long period of time. Oregon white oak does not achieve maximum productivity until 80 years of age (Peter and Harrington 2002). Based on counting growth rings on stumps and increment cores, it also can take up to 80 years for pines to grow to >15 in dbh (the typical size of squirrel nest trees in Klickitat County) on dry sites (M. Linders, pers. obs.). Commercial companies and DNR do not normally harvest oaks, but small landowners and developers harvest oaks throughout Klickitat County during land-clearing and road-building. The cutting of wood for fuel is generally unregulated and also contributes to the decline of oak woodlands (Larsen and Morgan 1998).

In Klickitat County, the number of forest practice applications and the number of acres logged rose markedly in the early 1990s due to increased lumber prices, salvage logging of beetle and drought-killed pines, and a perception that future restrictions on logging might have an increased economic impact on operations (WDNR 1996). From January 1994 through August 1999, at least 152 forest practice applications were approved within potential western gray squirrel habitat in Klickitat County (WDNR files).

Western gray squirrels are also affected by logging in the Okanogan, where late-successional forests have declined significantly (USDA and USDI 1996). The Okanogan and Wenatchee National Forest Plans have not contained specific prescriptions for western gray squirrels; these forest plans are currently being revised. Bartels (2000) reported finding 13 western gray squirrel nests along French Creek in Okanogan County in 1996; she could only find 1 nest in 2000 after logging occurred in 1996 and 1998, although nest trees, stringers of trees and riparian buffers were present after logging.

There have been few studies of the effects of timber harvest on tree squirrels in western pine or oak forests. Garrison et al. (2005) evaluated the effects of group-selection harvest, or small (typically <1 ha) clearcuts, on Douglas squirrels and western gray squirrels using point-count detections in black oak-dominated forest in California. They used paired 10.6 ha treatment and control plots in 4 study stands, and treatment plots contained 4 harvest units of 0.6 ha. Trees < 20 cm as well as 1 – 3 black oaks, safe snags and logs were retained. The harvest reduced stem densities and basal area of the treatment plots by about 30%. They did not detect a significant change in detections of western gray squirrels, and they concluded that the impact of group selection harvest on western gray squirrel populations was neutral. However, this was likely due in part to the very low frequency of detections before and after harvest (Garrison et al. 2005), the small scale of ground and forest stand disturbance, large amounts of unharvested adjacent habitat, and retention of small pines and a few large oaks (Garrison et al. 2005). The point count method may have adequately sampled Douglas squirrels, which are territorial and more vocal, but was poorly suited to sampling western gray squirrels, which rarely vocalize. Point count detections also say nothing about the productivity, survival, or recruitment of the squirrels present. Harvest plots could constitute sink habitat where reproduction was not succeeding (van Horne 1983). Garrison et al.'s (2005) study area also likely remained good habitat as the post-treatment mean basal area and stem diameters (25.5 m^2/ha and 40.7 cm dbh) met or exceeded those on the Klickitat Wildlife Area.

Patton et al. (1985) conducted an 8-year experimental study of the effect of harvest in Ponderosa pine on Abert's squirrel in Arizona. Squirrel home range size nearly doubled on the treatment plots and squirrel density was 0.32 squirrels/ha higher on control plots than harvest plots in the post-harvest period. Squirrel density increased in all plots because squirrels shifted and increased home ranges into both harvest and control plots because the surrounding areas were more heavily harvested. Harvest on treatment plots retained groups of trees around nests, heavily used feed trees, and around water sources. They attributed the difference in squirrel density between control and treatment plots in the post-treatment period to the larger number of trees (20 trees/ha) in the 30-74 cm dbh range that were important to the squirrels for food and cover (Patton et al. 1985). Dodd et al. (2003) investigated Abert's squirrel populations, habitat structure, and diets. They reported that squirrels moved to exploit seasonally available pinecones where forest thinning had promoted cone production, particularly where these stands were adjacent to high quality habitat. They characterized high quality habitats as those that exhibited basal area >35 m^2/ha, and >20 trees per acre in the 45.7-61.0 cm dbh (18-24") diameter class. Study sites with average or above squirrel recruitment had a minimum of 22 patches/ha of >5 interlocking canopy trees (interlocking was defined as <1.5 m separation; Dodd et al. 2003).

In 2003, WDFW initiated an experimental investigation of the effects of harvest on a squirrel population, and collected pre-harvest telemetry data on both WDFW lands and a timber company's lands. However, the company changed its plans and did not harvest the unit in 2005 as expected, and subsequently sold its lands. In addition, WDFW was not able to complete the harvest on its portion of the study due to demands on staff created by the School

Fire in Columbia and Garfield counties. The study was discontinued until additional funds and harvest units can be arranged.

Wildfire and fire exclusion. Both fire exclusion and subsequent wildfire can threaten western gray squirrel habitat by altering vegetation patterns and disrupting natural processes. Fire favors Oregon white oak and ponderosa pine woodlands by limiting pine recruitment and the encroachment of Douglas-fir and other vegetation, stimulating oaks to sprout (Kertis 1986). Successive fires kill conifer seedlings (Brown and Sieg 1996) and remove insect-infested trees, creating open, park-like stands dominated by ponderosa pine (Gruell et al. 1982, White 1985, Johnson et al. 1994, Fitzgerald 2005). This reduction in the number of seedlings is critical to minimizing competition for water and nutrients and ensuring the survival and productivity of remaining trees. The reduced competition increases available moisture, increasing resin flow and improving resistance to insect attack (Covington et al. 1997). Frequent burning also inhibits insects and disease by burning infected litter, and it reduces fuel loads, which keeps fires brief and flame lengths low (Agee et al. 2000, Fitzgerald 2005). Overall, fire helps to maintain the open character of woodland habitats and minimize the potential for destructive crown fires. Fire, as used by Native Americans, also increased the quantity of acorns and bulbs (Hanna and Dunn 1997) and caused a flush of new green vegetation, both of which would benefit squirrels. Peter and Harrington (2004) found that underburning 1–4 times in a 17-yr period seemed to contribute to more consistent and larger acorn crops for 10 or more years after the burn, but more frequent underburning may inhibit seed production. Hot fires eliminated acorn crops for one or more years afterwards. Ponderosa pine stands undergoing restoration on the Okanogan-Wenatchee National Forest in Washington were first thinned to reduce canopy cover and fuel loads, then prescribed burned. Remaining trees increased seed production within one year following the thin/burn treatment (P. Ohlson, pers. comm.).

In contrast, fire exclusion in ponderosa pine forests increases tree density, forest litter depth, and fuel loading. Covington et al. (1997) noted that in Arizona ponderosa pine forest, these changes in turn result in decreases in soil moisture, nutrient availability, growth and diversity of both herbaceous and woody plants, and stream flows, and increases in fire severity and size, and mortality in the oldest age class of trees. In mesic sites in Washington, fire exclusion facilitates invasion by Douglas-fir and other species, which increases the likelihood that fire intensity will increase. When unchecked by fire, Douglas-fir can grow 3–5 times faster than oak (Franklin and Dyrness 1988) and can overtop and suppress the shade-intolerant oaks and pines (Ryan and Carey 1995a, Agee 1993). Influx of exotic vegetation such as Scot's broom is also aided by fire exclusion, and is a compounding factor in the Puget Sound region. In areas where fire control has been extremely effective, there are forested stands and landscapes in the ponderosa pine/Douglas-fir types that would have burned 10 to 12 times by now based on presettlement fire history, but have not burned at all (Agee 1993). By allowing a build up of natural fuels, these areas are subject to increased risk of large catastrophic fires (Agee 1993, WDNR 1996, Graham and Jain 2005) that threaten both western gray squirrels and their habitat. Wildfires under overstocked, high fuel load conditions often kill large expanses of vegetation, consume the forest litter, volatilize nutrients, and result in the spread of weedy exotic vegetation (Graham and Jain 2005).

In the more mesic portions of western gray squirrel habitat, periodic fires and active management of oak and pine forests are necessary to halt encroachment and domination by Douglas-fir, true fir, and exotic or invasive species (Barnhardt et al. 1987, Reed and Sugihara 1987, Foster 1997). Management techniques that can reverse the impacts of fire exclusion and reduce the risk of large-scale crown fires are being developed and include commercial thinning, pre-commercial thinning, mowing, pruning, planting of fire-tolerant and insect- and disease-resistant species, development of fuel breaks, prescribed fire, mechanical and hand piling of fuels and short term suppression of insects (Lemkuhl et al. 1994, Foster 1997, Agee et al. 2000, Okanogan and Wenatchee National Forests 2000, Fitzgerald 2005, Graham and Jain 2005). Covington et al. (1997) report that burning alone results in high mortality in older ponderosa pines, and that some combination of thinning, manual fuel removal, and prescribed burning is necessary to restore these systems to natural conditions. The U.S. Forest Service is developing a management strategy for dry forest vegetation in the Okanogan, and other landowners also recognize the need for change in fire exclusion policies. Its aim is to reduce fuel loads and decrease the density of small trees in dry forest types (Okanogan and Wenatchee National Forests 2000). If implemented fully, > 2.5 million acres of forest would be affected, although only a small percentage would be considered western gray squirrel habitat. Harrod et al. (2007a,b) evaluated burning and thinning, alone and in combination, in Okanogan-Wenatchee National Forest. They reported that thinning combined with late-season prescribed burns was a promising management strategy for restoring pre-settlement structure of ponderosa pine forest. While opening the understory and thinning over-stocked stands could benefit western gray squirrel habitat, the rate and manner in which the strategy is applied will determine its effect on squirrels. Dodd et al. (2003) cautioned that Abert's squirrel populations and hypogeous fungi may be negatively impacted by wide-scale forest restoration treatments that substantially reduce basal area and the incidence of interlocking canopy trees. Lehmkuhl et al. (2004) indicated that shifting stand microclimate to drier conditions will result in lower richness and biomass of truffles, but would favor species associated with drier conditions (e.g. *Rhizopogon parksii*, *R. vinicolor*, *R. pachyspora*, and *Melanogaster tuberiformis*). They suggested that the retention of the largest woody debris and retaining patchiness in stand density and species composition may ameliorate the impact of dry forest restoration treatments on truffle richness and abundance and consequent impacts on mycophagous squirrels. This would be consistent with the observations of States and Gaud (1997) in Arizona.

Population Size and Isolation

Small population size and isolation is a potentially important factor influencing the continued existence of western gray squirrels in Washington. Western gray squirrel populations naturally fluctuate with mast production and disease. This natural variability puts smaller populations at greater risk of local extinction. The negative effects of habitat change are amplified when populations have dropped to low levels. For example, dispersal by juveniles is typically advantageous in widespread and connected populations. However, it may become detrimental in isolated populations if dispersing juveniles are a net loss to the population and there is no compensating immigration. The Puget Trough population is very small and cannot be expected to persist long without augmentation. Weston (2005) reported that western gray squirrels seemed to be extirpated from areas of suitable habitat in the northern Willamette Valley, Oregon, that had become isolated by a combination of highways, habitat changes and natural barriers. Many authors indicate that long-term survival (greater than 100 years) of isolated populations requires many more individuals than populations that occasionally exchange genetic material with other populations (Lande and Barrowclough 1987, Dawson et al. 1987, Grumbine 1990). An increasing number of studies indicate that goals to maintain viable populations of vertebrates need to be in the order of several thousands, rather than hundreds (Reed et al. 2003), although much smaller populations may sometimes persist for some time (Pacheco 2004).

In a review, Garner et al. (2005) report that based on microsatellite markers, there has been a pervasive and consistent loss in genetic diversity in mammal populations that face a demographic threat. They concluded that by the time species receive official conservation status, they have already lost a substantial portion of their genetic variation. The isolation of small populations typically results in a loss of genetic quality that may require the introduction of individuals to counteract loss of fitness (Lacy 1987, Reed and Frankham 2003). Lack of genetic vigor may reduce the viability of populations and their ability to expand into adjacent habitat. Inbreeding depression has contributed to declines and extinctions of several species in the wild (Brook et al. 2002). Genetic health, represented by adequate genetic heterogeneity, may be an important issue in western gray squirrel populations in Washington, particularly in the Puget Trough. Warheit (2003) reported that the Washington populations of western gray squirrel showed reduced genetic diversity at all measures compared to populations in Oregon and California. Observed and expected heterozygosities in Oregon were twice that in Washington, and the number of alleles per locus is lower for each of the Washington populations compared with populations south of the Columbia River. Warheit (2003) noted that the reduction in genetic diversity may be a function of genetic drift resulting from the small population sizes in Washington.

Disease

Episodic outbreaks of disease, particularly Notoedric mange, seem to be characteristic of many squirrel species. Disease has had a significant impact on populations of western gray squirrels in Washington since at least the early 1930s. Local residents believe that western gray squirrel populations in Klickitat County have never recovered to the numbers present prior to disease outbreaks in the 1930s and 1940s. Mange apparently reduced the western gray squirrel population on the Oak Creek Wildlife Area in Yakima County in the 1940s and 1950s and seems to have contributed to or resulted in local extinction (Stream 1993, WDW 1993). In Klickitat County, notoedric mange was prevalent in 1998–99 and present at varying levels from 2000–2004 (Linders 2000, Cornish et al. 2001, Vander Haegen et al. 2005). Food shortage induced stress seems to contribute to the likelihood and severity of mange outbreaks. Disease effects can be magnified when populations become small (e.g., black-footed ferret) (Gilpin and Soule 1986). The fluctuations in population size resulting from mange increases the risk of local population extinction; and population fluctuation is an important factor in determining the population size needed to achieve long-term viability (Frankham 1995, Vucetich and Waite 1998). Research is needed on the effects of mange on western gray squirrel populations, and the efficacy of treatment of individuals captured for translocations.

West Nile Virus has been confirmed in western gray squirrels in California. It is not known if it will cause significant numbers of mortalities in healthy western gray squirrel populations, but any additional mortality factor can be important to the small populations in Washington.

Other Human-related or Natural Factors

Introduced competitors and potential competitors. Introduced eastern gray squirrels and fox squirrels and Merriam's and eastern wild turkeys may compete for food and habitat with western gray squirrels. Eastern gray squirrels currently overlap with the range of the western gray squirrel in the Puget Trough, Chelan County, Skamania County and southwest Klickitat County. Fox squirrels overlap with western gray squirrels in the Okanogan. Where eastern gray and fox squirrels are present, they probably compete directly for the same food and nest resources and may add to the instability of marginal western gray squirrel populations. Eastern gray squirrels are more ecologically adaptable than western gray squirrels and can produce two litters per year, while western gray squirrels produce only one per year. Eastern gray squirrels often thrive in suburban areas and over the past decade, they have colonized areas from Vancouver, Washington east along the Columbia River. They are quite common in Stevenson and White Salmon, and were recently reported 4 mi northeast of Lyle in Klickitat County (B. Weiler, pers. comm.), a distance of >79 mi from Vancouver. Historically, western gray squirrels may have been found throughout this part of the Columbia River Gorge, but they are now limited to the eastern third of the Gorge. While eastern gray squirrels are able to thrive in urban areas where western gray squirrels cannot, they also may invade large tracts of riparian habitat formerly occupied by western gray squirrels. Many of these areas also contain abandoned nut and fruit trees, increasing the potential for successful colonization. Where eastern gray squirrels have been introduced in Europe, they are displacing the native European red squirrel (Bertolino and Genovesi 2002, Gurnell et al. 2004). In mixed deciduous forest, eastern gray squirrels replaced red squirrels in 3-5 years (Wauters et al. 2005). A concerted effort is being made to control them to conserve the native red squirrel and to limit damage to public forests (Currado 1998, Dagnall et al. 1998)

Research is needed to evaluate the threat to western gray squirrels posed by competition with eastern gray squirrels. Competition with eastern gray squirrels was not directly observed in studies on Fort Lewis during the 1990s (Ryan and Carey 1995b, Bayrakçi 1999). At that time, most observations of eastern gray squirrels were adjacent to residential areas (Ryan and Carey 1995b, Bayrakçi 1999), which are generally avoided by western gray squirrels in Washington. However, hair snag surveys conducted since February 2004 indicate that eastern gray squirrels have begun to colonize a number of remote locations on Fort Lewis, many miles from human developments (Fimbel 2004a).

Wild turkeys are a potential competitor with western gray squirrels, but there are no data on the potential impact of turkeys on western gray squirrel populations. Pine seed and acorns are primary foods of western gray squirrels and wild turkeys will congregate where these foods are abundant. Western gray squirrels begin feeding on green pine nuts in spring and feed on them all summer and fall (Linders 2000), and also feed on immature acorns (M. Vander Haegen, pers. comm.). Turkeys forage on the ground so acorns and pine seed are not available to them until they mature and fall to the ground; competition with squirrels would occur seasonally for pine seeds and acorns on the ground. Turkeys have been introduced numerous times in Washington over a period of 80 years (Cope et al. 2003). Prior to increased augmentations in the late 1980s, however, turkey populations were small and in limited areas; annual harvest averaged 65 birds/year. Recent releases included: 268 eastern wild turkeys in Thurston, Pacific, Grays Harbor, and Mason counties in 2000; 700 Merriam's in Chelan and Okanogan counties in 2001–2002; and 574 Merriam's turkeys in Kittitas and Yakima Counties during 1999–2001 (Cope et al. 2003). No turkeys were released near western gray squirrel populations (Cope et al. 2003). These and other translocations in the last 20 years have been very successful and the wild turkey harvest in 2002 exceeded 5,000 birds (Cope et al. 2003).

Turkeys are expanding their range in the Klickitat, Okanogan, and Puget Trough regions. Turkeys were commonly seen on sites used by western gray squirrels throughout Klickitat County during squirrel surveys conducted from 1994–1997 (M. Linders, pers. obs.). In 2003, the turkey population in Okanogan County was thought to be increasing and expanding its range, colonizing tributary streams of the lower Methow (Cope et al. 2003). Turkeys may eventually overlap with squirrels in the Puget Trough and the Okanogan. Research is needed to determine if, and to what degree, turkeys have an adverse impact on squirrel populations that could affect recovery efforts. WDFW plans to participate in a cooperative study of wild turkey diets in Washington and Oregon.

Military training. Military training activity at Fort Lewis may affect western gray squirrels (Bayrakçi 1999). Western gray squirrels are known to be wary and secretive, avoiding disturbed areas and human activity (Cross 1969, Rodrick 1986, WDW 1993). The amount of activity and the number of troops stationed on Fort Lewis has varied over time; currently, more heavy mechanized vehicles are stationed there than ever before (G. Stedman, pers. comm.), and they are currently planning the infrastructure to accommodate the training of an additional brigade (D. Clouse, pers. comm.). Military training could impact squirrels directly through disturbance during critical reproductive or foraging periods, or could result in avoidance of areas where foot soldiers are training. Indirect impacts could include habitat degradation through soil compaction and the spread of fire. Records describing the specific timing and type of training in and around oak woodlands on Fort Lewis are lacking, making it difficult to assess their effects. Training is typically periodic, primarily occurring on roads and prairies adjacent to and within oak woodlands. While there are some restrictions on maneuvering in prairies, they do not extend to oak areas. While training likely has some effect on squirrels, the Fort has preserved habitat within its boundaries which has allowed the Puget Trough population to persist while being eliminated elsewhere.

Grazing. The specific relationship between grazing and western gray squirrel habitat requirements has not been the focus of research. The short term effects of light to moderate grazing on western gray squirrel habitat is unknown. Historical overgrazing by livestock contributed to the existing dense and fire-prone conditions of dry eastern Washington forests (Madany and West 1983, Zimmerman and Neuenschwander 1984, Savage and Swetnam 1990, Agee 1993, Belsky and Blumenthal 1997). The introduction of large numbers of grazers reduced the biomass and vigor of understory grasses and sedges; with reduced competition from herbaceous vegetation, more tree seedlings became established (Belsky and Blumenthal 1997). Some grasses of ponderosa pine forests are known to contain allelopathic chemicals that inhibit germination of ponderosa pine seeds (Madany and West 1983). Also, by consuming the herbaceaous vegetation, grazers eliminated the fine fuels that historically carried ground fires, and dense stands of saplings and pole-sized trees became established. Rummell (1951) compared two very similar isolated plateaus in Yakima County. Meeks Table, which had not been grazed, had an open park-like stand of ponderosa pine, luxuriant grasses, and low tree regeneration. In contrast, Devils Table, which had been grazed seasonally for 40 years, had a sparse herbaceous layer and over 8,000 saplings (<4 in dbh) per hectare of pine, Douglas-fir, and western larch. Increment cores and fire scars indicated that both sites had a similar fire history of light ground fires, and they were similar in all other respects, except that Meeks Table was inacessible to livestock. Rummel (1951) concluded that the high tree density on Devils Table was fostered by heavy livestock grazing rather than lack of fire. Harrod et al. (1999) describing the historical ponderosa pine forest in Chelan County, noted that, "The current high density of smaller trees has likely resulted from a pulse of *P. ponderosa* establishment in the 1920s from heavy grazing shortly after the turn of the century."

Increased soil moisture and disturbance of the sod layer by grazing permits shrub and seedling establishment, favoring Douglas-fir (Hedrick and Keniston 1966). Over-grazing can eliminate some native forbs and may inhibit growth of some mycorrhizal fungi (Bethlenfalvay and Dakessian 1984, J. Trappe, pers. comm.). Where livestock or wild ungulates are concentrated, oak-conifer communities may also be impacted by damaging root systems, altering soil moisture retention, and compacting soils (McCulloch 1940, Dunn 1998, Larsen and Morgan 1998). In locations where prescribed burns cannot be used to restore and maintain an open understory, livestock may have some utility in reducing fine fuels that would carry a wildlfire. The long term effect of livestock appears to be an increase in woody understory (Rummel 1951, Belsky and Blumenthal 1997). Oaks are a food of last resort for cattle, but they will browse oak sprouts after grass has dried out (Larsen and Morgan 1998). Larsen and Morgan (1998) state that grazing is not recommended where oak sprouting and sapling growth are being encouraged, within riparian zones, or where acorn production is desired but scarce. They recommend rotating grazing areas to allow vegetation to recover and oak regeneration to occur.

Grazing is widespread in Klickitat County and heavy grazing may be a localized problem, but in the short-term, it may not be an important or widespread issue for western gray squirrel habitat. Portions of Klickitat County are open range so landowners who do not want grazing to occur on their land have to erect fences to exclude livestock. Approximately 3,840 ac of the Soda Springs Unit of the Klickitat Wildlife Unit is leased for spring/summer grazing to improve forage conditions for deer that involves 160 animal units with cattle present two out of three years (Ellenburg and Dobler 2006). Cooperative range management plans between cattlemen and timber companies in Klickitat County are in place on some forested land. Livestock grazing is also widespread and a significant economic activity in Okanogan, Chelan and Yakima counties. In the past, winter concentrations of elk at feeding stations in Yakima County degraded some riparian habitat, but all these have been shifted up out of riparian habitat. One feeding site remains on Nile Creek, but it is not considered good squirrel habitat (J. McGowan, pers. comm.).

Incidental hunting mortality. While shooting western gray squirrels and other native tree squirrels is prohibited in Washington, the California ground squirrel, eastern gray and fox squirrels can be legally hunted with any hunting license; they can be hunted year-round and there are no bag limits. No records are kept on the level of harvest, but a system to track harvest of these and other species of ‘unclassified wildlife’ is being developed (M. Cope, pers. comm.). Shooting of ground squirrels occurs in habitat used by western gray squirrels, which have been killed when mistaken for ground squirrels (D. Morrison, pers. comm.). No estimate is available on the level of mortality resulting from mistaken identity. The potential for mortality of reintroduced western gray squirrels from shooting, particularly on WDFW lands, may require education efforts or local restrictions.

Sudden oak death syndrome and related threats. In 1994–1995, a new disease, ‘sudden oak death syndrome’, began killing oaks in coastal California. Since then, sudden oak death has become epidemic, spreading to over 13 counties along 300 km of coastal California (Rizzo and Garbelotto 2003, OMTF 2004). Tens of thousands of trees have been killed, and infection rates range from 4–70% (Rizzo and Garbelotto 2003). Sudden oak death is caused by a newly identified species known as *Phytophthora ramorum*, part of a group of fungus-like organisms, called Oomycetes, that caused the Irish potato famine and the Port-Orford cedar root disease (UCCEMC 2001, WSDA 2006). The disease may be spread through infected wood, soil and rainwater, but is most readily transported by the movement of infected plants and plant parts. The geographic origin of this pathogen has not been determined. Unlike most *Phytophthora* species, *P. ramorum* enters through tree bark, and spreads readily in water. Inside the tree, the fungus produces enzymes that dissolve the inner layers of bark. As the tree becomes weakened, it becomes vulnerable to bark beetles, which burrow into the tree and kill it. To prevent the infection of healthy trees, researchers recommend avoiding disturbance to the root zone, preventing frequent irrigation, and minimizing injuries to stems and lower limbs.

At least 30 plant species from 12 families act as hosts for the disease, and 30 additional species are potential hosts based on susceptibility to infection in laboratory inoculations (Rizzo and Garbelotto 2003, OMTF 2004). This represents almost all of the woody plant species found in mixed evergreen and redwood forests from central California to southern Oregon. Tanoaks (*Lithocarpus densiflorus*), coast live oaks (*Quercus agrifolia*), black oaks (*Quercus kelloggii*), and Shreve’s oaks (*Quercus parvula* var. *shrevei*) are often killed by the disease. Oregon white oak and other species in the white oak group have not yet been identified as a host species for sudden oak death and the likelihood of it becoming infected is unknown. Effects on most host plants are limited to cankers and lesions on leaves and stems, or dieback of branches and shoots, but host plants also play an important role in the spread of the disease by acting as reservoirs; it is thought that forests with a diversity of plant hosts may be more susceptible to sudden oak death (Rizzo and Garbelotto 2003). In August 2001, the disease was found in Curry County, Oregon despite cooperative efforts to control its spread. In 2003, plant nurseries in Washington, Oregon, California, and British Columbia began reporting the disease in nursery stock (ODA 2006), and by June 2004, the disease had been detected in 125 nurseries in 17 states (OMTF 2004). Both state and federal departments of agriculture are working to restrict the movement of potential host plants. The Washington State Department of Agriculture had detected the disease in 20 nurseries in western Washington (WSDA 2006). Infected nurseries have been quarantined under federal order and procedures to eradicate the disease are in effect.

The potential for serious negative impacts to wildlife is great, due to the hundreds of vertebrate and invertebrate species associated with western oaks (Larsen and Morgan 1998, Rizzo and Garbelotto 2003). In addition to oak trees, other host plants less affected by the disease but known to produce food eaten by western gray squirrels include Douglas-fir, bay laurel, manzanita (*Arctostaphylos manzanita*), bigleaf maple, California hazelnut, and poison oak (Stienecker 1977, Ryan and Carey 1995a). The loss of oaks as seen in California also has the potential to cause large-scale ecosystem changes by causing shifts in preferred foods and even altering the ecology of mycorrhizal fungal communities (Rizzo and Garbelotto 2003). In addition to the impact of tree loss and associated mast on wildlife, diseased trees are structurally unstable and dry leaves can present a fire hazard.

Filbert worms. Numerous insect larvae were found feeding on acorns in Klickitat County in 2001 (M.

Vander Haegen, pers. comm.). The larvae have been identified as a form of filbert worm (*Cydia latiferreana)*, a significant economic pest from the Columbia River south into Oregon and California (E. LaGasa, pers. comm.). Historical information from the region indicates that filbert worms can affect >80% of an acorn crop. LaGasa stated that he is also aware of at least two introduced exotic defoliating pests on Washington oaks that have not previously been recorded in the U.S. He speculated that other pests and pathogens of oaks that are new to the U.S. or North America may also be present.

CONCLUSIONS

The western gray squirrel is a state threatened species with three separate populations in Washington, estimated to total several hundred to 1,400 individuals. Conifer dominated stands of mature pine and oak with interconnected crowns provide the best habitat for western gray squirrels in Washington. High quality habitat is limited and population densities are low relative to populations in Oregon and California. The isolated nature of the three populations and the potential for fragmentation within them pose added risks to populations.

The primary threat to the squirrel is continued habitat loss and degradation resulting from a combination of development, roads, and logging, as well as an altered fire regime due to historical over-grazing and fire exclusion. Habitat changes affect squirrels both directly and indirectly by diminishing the food supply, altering or destroying nest sites and escape cover, and increasing the risk of death by disease, automobiles and predation. Western gray squirrel habitat is naturally fragmented by topography and is, therefore, easily eroded by the destruction of natural corridors such as arboreal connections in riparian areas and elsewhere. Timber harvest that removes large conifers and results in evenly spaced trees with few or no canopy connections, and development that removes oaks and fragments habitat, likely reduce squirrel populations.

Cooperative management plans with public and private landowners could help to improve habitat quality and prevent further loss and degradation of oak-conifer communities. Research is needed to describe the effects of a range of timber harvests on western gray squirrel populations.

Notoedric mange and road-kill are sources of mortality that may periodically or chronically depress populations. Introduced eastern gray squirrels and wild turkeys, and California ground squirrels may be competing with some populations. Non-native fox squirrels also appear to be expanding their range in the state and may pose an added problem in the future.

The western gray squirrel population in the Puget Trough will require aggressive intervention to prevent extinction. Surveys that documented the persistence of western gray squirrels recently on the Yakama Reservation and the Stehekin Valley are encouraging; additional surveys are needed to better determine the distribution and size of this population and the population in the North Cascades Re-

PART TWO: RECOVERY

The three remaining populations of western gray squirrels in Washington are isolated from each other and are likely to remain so in the future. Recovery will involve partnerships with landowners, federal, state, and local agencies, and private conservation groups. The majority of occupied squirrel habitat in Puget Sound is managed by the Department of Defense; in the Klickitat, it is under private ownership; and in the Okanogan, it is managed by the US Forest Service and private landowners. Incentive programs and partnerships may prove helpful to allow private landowners to retain functional western gray squirrel habitat and make sustainable timber production a viable option. Recovery will need to address maintaining and increasing the current populations, expanding those populations into adjacent areas and establishing additional populations. Some portions of the former range – such as those where little oak-conifer woodland remains and where there are many roads and urban or suburban development – are not likely to be restored to a condition suitable for western gray squirrels. Some intervening areas of unoccupied habitat may, however, serve a connectivity function, particularly in the Cascade Mountains, and possibly lands between the Puget Sound and the Columbia River in the areas described by Cassidy et al. (1997) as the Cowlitz River and Willamette Valley vegetation zones. Factors that need to be addressed for recovery include protection and enhancement of populations and habitat, and determining and addressing other factors limiting populations.

Squirrel recovery areas. Western gray squirrel recovery activities will occur in the three regions currently occupied by western gray squirrels and adjacent areas that had historic squirrel records (Fig. 12). Conservation activities in the three regions with existing populations will focus on protecting and augmenting those population as needed, and protecting and restoring habitat. Additional areas that historically supported squirrels should be evaluated for the need for augmentation or feasibility of reintroductions; sites to evaluate include the Oak Creek and Wenas Wildlife Areas, and the Yakama Reservation. Recovery action priorities are identified for each of these areas (Table 12). Habitat that may be suitable in areas adjacent to and between the three regions with extant populations should be managed to provide connectivity. Squirrels might be able to disperse through or occupy scattered locations

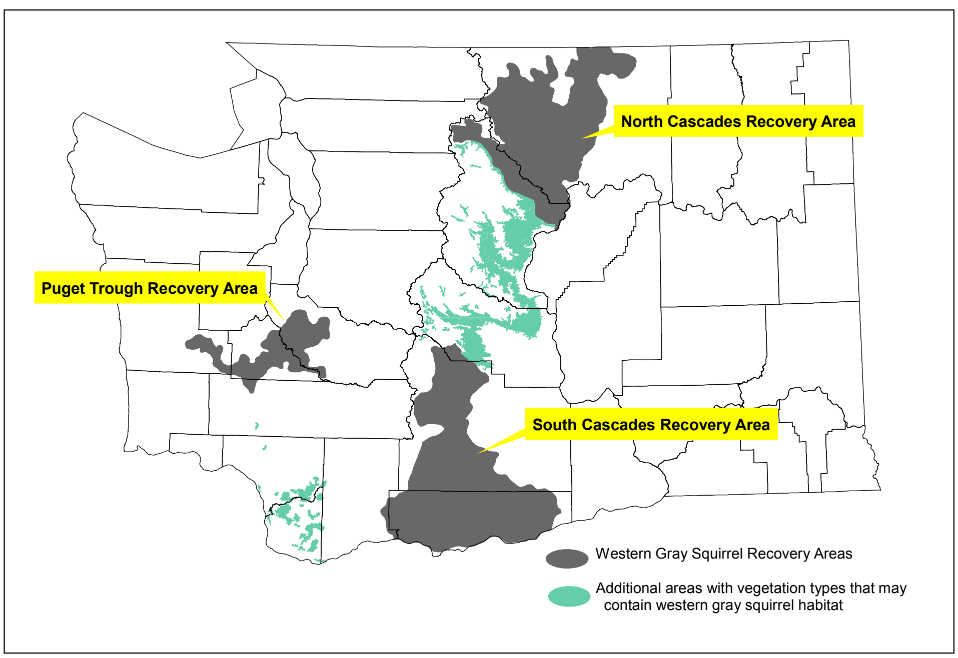


Figure 12. Western Gray Squirrel Recovery Areas in Washington.

Table 12. Population presence, relative habitat condition, and recovery action priorities for three Western Gray Squirrel Recovery Areas in Washington.

Recovery Areas	Known population present	Habitat condition	Recovery action priority [a]					
			Augment[b]	Monitor	Survey	Map Habitat	Improve habitat	Research limiting factors
South Cascades Recovery Area								
Klickitat region	Yes	Varied		1	2	3	1	1
Oak Creek Wildlife Area	No	Varied	2			2	2	
Wenas Wildlife Area	No	Varied	2			3	2	
Yakama Reservation	Yes	Varied	2[c]		1	2	1	1
North Cascades Recovery Area								
Stehekin/northern Lake Chelan area	Yes	Good	2[c]	1		2	2	1
Southern portion	Yes	Varied		1	1	3	2	2
Northern portion	Unknown	Good	3[c]	2	1	2	2	
Puget Trough Recovery Area	Yes	Degraded	1	1	2	2	1	1
Additional areas that may contain squirrel habitat	No	Varied			3[d]			

[a]Priority 1 = high; 2 = medium; 3 = low
[b]Augmentation or reintroduction may be required to establish or enhance breeding populations.
[c]Evaluate the need for augmentation.
[d]Follow up on sighting reports to determine if additional populations exist outside recovery areas.

between the Klickitat and Okanogan (Chelan and Kittitas counties) and along the Columbia Gorge west of Klickitat County, and in the Puget Trough between the Puget Sound and Klickitat populations.

RECOVERY GOAL

The goal of the recovery program is to restore and maintain healthy populations of western gray squirrels in a substantial portion of the species' historic range in the state. Healthy populations would be large enough to readily recover from fluctuations due to disease and extremes in weather and adapt to changes in habitat. This will require increasing the number and distribution of western gray squirrels in the state.

INTERIM RECOVERY OBJECTIVES

More information on the amount of suitable habitat available and western gray squirrel population dynamics is expected to become available in future years which will aid in refining recovery objectives. In the interim the following recovery objectives have been developed. These objectives are based on current knowledge and principles explained in the rationale.

The western gray squirrel will be considered for downlisting to State Sensitive when:

1) the following population levels are achieved:

- a total population of 3,300 adult western gray squirrels in the South Cascades Recovery Area;
- a total population of 1,000 adult western gray squirrels in the North Cascades Recovery Area;
- and a population of >300 adults in the Puget Trough Recovery Area;

2) Management plans, agreements, regulations, and/or other mechanisms are in place that effectively protect the habitat values for western gray squirrel populations.

Rationale

A ‘viable’ western gray squirrel population relates to its size, distribution, and ability to maintain genetic heterogeneity over the long-term. It also relates to the ability of a population to withstand fluctuations in population and recruitment associated with annual variation in food supplies, predation, disease and habitat quality. Lack of genetic health may be reflected in declining productivity and hence in declining population size, regardless of other factors such as habitat. There is no universally accepted definition of what constitutes a ‘viable’ population in the scientific literature, but generally a minimum viable population is the smallest size at which populations can maintain genetic variability over time. Many conservation biologists believe that a population of a few thousand or more is desirable for long-term persistence (Frankham et al. 2002, Reed et al. 2003). Smaller populations are subject to erosion of genetic diversity and are at higher risk of decline and eventual extinction as a result.

Population sizes of western gray squirrels are difficult to estimate, but it is the ‘effective population size’ that determines whether the population is large enough to maintain genetic health and avoid inbreeding. The effective population (N_e) is the proportion of a population (N) that can be expected to pass on their genetic information from one generation to the next (Frankham et al. 2002). In order to estimate the minimum viable population size for western gray squirrels in Washington, the effective population size needs to be determined (Reed et al. 1986). N_e is affected by fluctuations in population size, variance in litter size, and unequal sex ratio (Frankham 1995). Population fluctuations are the most important factor influencing the effective size of a population and are a well-established feature of the population dynamics of tree squirrels (Gurnell 1987). In general, an N_e of about 500 is the minimum N_e that could be expected to maintain the species evolutionary potential (Frankel and Soulé 1981, Frankel 1983, Reed et al. 1986, Frankham et al. 2002:530). The relationship between the census population (N) and N_e is unknown for western gray squirrels because of the lack of sufficient survey data and understanding of demography and population dynamics. Charlesworth (1994) estimated the ratio of N_e /N for eastern gray squirrels at 0.59, but he did not include the effect of population fluctuations, the most important factor in reducing N_e below N for many species (Frankham 1995, Vucetich and Waite 1998). Frankham et al. (2002) reviewed estimates of N_e from 192 studies of a wide variety of taxa, and found that for populations with long term census data, N_e averaged 11% of the census population (N). Studies of other mammals have reported N_e/N ratios of 0.069 for bison (*Bison bison*), 0.18 and 0.59 for northern hairy-nosed wombat (*Lasiorhinus krefftii*), 0.44 for bighorn sheep (*Ovis canadensis*), 0.18-0.43 for Rodrigues fruitbat (*Pteropus rodricensis*; included adult+juveniles), and 0.42-0.68 for rabbits (*Oryctolagus cuniculus*). In most of these studies, N was the adult population. Western gray squirrel populations seem to fluctuate, perhaps dramatically as a result of disease, so the N_e /N is likely to be near the low end of this range. If we assume a N_e /N ratio of 0.15 for western gray squirrels, this indicates that an adult population of >3,300 western gray squirrels may be needed to provide the desired minimum N_e of 500 to maintain genetic diversity and be considered a viable population. Additional research is needed to determine the effective population size and whether 3,300 would constitute a viable population.

Washington currently has three separate populations of western gray squirrels. Ideally, each population would be >3,300 adults, but the South Cascades may be the only region able to support that many. Habitat improvements and translocations may allow the Klickitat and Okanogan populations to increase substantially. The average spring density of squirrels on the Klickitat Wildlife Area is estimated to be 0.185 squirrels/ha (Vander Haegen et al. 2005), but the wildlife area may have the highest density of western gray squirrels in Washington. A population of 3,300 would require 33,000 ha of habitat with an average density of 0.1 squirrels/ha. The 2002 revision of the Rodrick (1999) map of suitable habitat in Klickitat County identified about 155,000 ha, but large portions of this habitat may be only marginally suitable Douglas-fir types or otherwise be in an unsuitable condition. Additional work will be needed to refine habitat mapping and estimates of the amount of habitat needed to support western gray squirrels in this and other regions.

The North Cascades Recovery Area appears to have substantial area of forest types that may contain habitat, but how much is suitable for western grays squirrels is unknown. This region lacks the oak component present elsewhere but contains ponderosa pine/mixed conifer habitat used by squirrels. It represents the northern extreme of the species range and home range sizes are about twice as large in the Okanogan as in Klickitat County (Gregory 2005). A better understanding of habitat use is needed to improve delineation of suitable habitat in the North Cascades Recovery Area and to determine if a population of 1,000 squirrels is an appropriate recovery objective. Maintaining a healthy population in the Okanogan may require periodic infusions of squirrels from elsewhere to avoid a decline in genetic diversity.

The Puget Trough Recovery Area cannot support a population large enough to be considered viable for the long term (i.e.>100 years) without periodic augmentation. This zone contains about 6,424 ha of oak types, much of it in scattered patches (Ryan and Carey 1995a, GBA Forestry 2002, Chappell et al. 2001), and it may not be able to support more than a few hundred squirrels. As is the case for the North Cascades, maintaining a population in the Puget Trough may require periodic translocation of squirrels from elsewhere to maintain genetic diversity.

Ideally, the three squirrel populations would be connected by periodic dispersers moving between them; in this case the combined populations could be considered one and the total population considered in evaluating viability. The amount of immigration needed to connect squirrel populations genetically is not known, but generally movement of 1–10 individuals per year is enough to prevent genetic isolation (Mills and Allendorf 1996); this assumes that these dispersing individuals breed successfully and movement is not in one direction. Although some suitable habitat may exist between the three populations, the distances are great and the intervening habitat may be marginal at best, so the three populations may never exchange individuals without direct intervention. Recovery of viable populations may require maintaining genetic connectivity between the separate populations by a program of translocations and genetic monitoring, but wider distribution of western gray squirrels will reduce the risk to populations from stochastic events, such as mange epidemics, mast crop failure and wildfires.

Meeting recovery objectives will require improvements in habitat quality, increases in population numbers and expansion of occupied areas. Once the recovery objectives are achieved, the species will be evaluated for down-listing from Threatened to Sensitive. A state Sensitive species is defined as a species "...that is likely to become endangered or threatened in a significant portion of its range within the state without cooperative management or removal of threats" (WAC 232-12-297). Once the western gray squirrel is down-listed to Sensitive, a management plan would be prepared outlining management needs and objectives to de-list the species. Recovery objectives may be modified as more is learned about the habitat needs, disease, and population structure of western gray squirrels. Data on vital rates, dispersal and population dynamics, as well as a better understanding of habitat needs and habitat capability, are necessary to more accurately assess what population sizes are needed and possible to achieve with available habitat.

RECOVERY STRATEGIES AND TASKS

1. Monitor and survey western gray squirrel populations in Washington.

1.1 Monitor the status of known western gray squirrel populations.

1.1.1 Develop protocols for long-term monitoring of squirrel populations.

Monitoring of western gray squirrel populations will be needed to determine when recovery objectives are achieved, to detect western gray squirrel population changes, and to understand any periodicity and consequences of disease outbreaks, mast crop failures and other factors influencing population dynamics. Protocols need to be developed that describe the procedure, frequency and extent of monitoring sufficient to determine occupancy, distribution, and abundance of squirrels. These may include live-trapping, and sight, nest, or hair snag surveys. While observation of active nests may be useful for detecting presence of squirrels, it may not be useful as a long-term indicator of population trends because of difficulties with persistence of nest materials, changes in color and condition of nest materials within and between years, and timing of surveys. Techniques such as hair snag surveys may prove to be useful for detection and long-term monitoring (Fimbel 2004a). A rigorous test of survey methodology is needed to evaluate the efficacy of different monitoring techniques for assessing occupancy, numbers of squirrels, and population trends.

1.1.2 Delineate squirrel analysis units within recovery areas.

As needed, subdivide recovery areas with the input of a working group or cooperators to facilitate monitoring surveys and other management activities. These could be done using watershed boundaries or other appropriate or useful subdivisions of the recovery areas. Sampling should be well distributed within suitable habitat in each recovery area.

1.1.3 Monitor population trends.

With the assistance of cooperating agencies, monitor western gray squirrel populations in Washington with periodic surveys according to the protocols developed. Revise population estimates as data becomes available.

1.2 Survey vegetation types that may contain western gray squirrel habitat to further delineate Washington distribution.

Surveys should be conducted in potentially suitable habitat to identify areas where additional squirrel colonies may exist. Systematic surveys should be conducted where habitat quality or sighting evidence indicates western gray squirrels may be present. Hair snag surveys, trapping or baiting should be used, if necessary, to confirm presence of western gray squirrels. Areas adjacent to known or recently occupied sites should be a higher priority than areas with limited historic evidence or lower- quality habitat.

1.3 Facilitate cooperative surveys, monitoring, and data collection and advise recovery actions.

1.3.1 Form one or more working groups of interested cooperators to facilitate coordinated surveys and information exchange.

1.3.2 Coordinate data exchange and cooperative survey efforts with the U.S. Forest Service, National Park Service, WDNR, Yakama Nation, Fort Lewis, McChord AFB, timber companies, county governments, conservation organizations and other cooperators.

Work with the partners through the working group(s) to develop survey techniques and protocols and coordinate monitoring of occupied habitat and surveys of habitat that appears to be suitable.

1.3.3 Maintain a statewide database of western gray squirrel survey efforts and detections.

The Wildlife Survey Data Management (WSDM) section at WDFW, Olympia, currently maintains a statewide database of survey information on western gray squirrels. To be fully effective, area surveyed, along with positive and negative results, must be reported to WSDM to insure accurate and efficient retrieval and to avoid duplication of efforts. Work with cooperators to solicit data on western gray squirrel surveys and results.

2. Protect western gray squirrel populations in Washington.

2.1 Identify human-related and natural sources of mortality.

Identify major mortality factors, both human-related and natural, for local populations through intensive monitoring and research activities.

2.2 Minimize factors contributing to mortality and competition.

Implement management strategies that will help reduce mortality from sources such as road kill and illegal and accidental shooting. Where reintroductions or translocations are planned, evaluate the need for reducing eastern gray squirrels.

2.2.1 Reduce roadkill mortality.

Identify and prioritize road segments where roadkills are frequently occurring and work with the Washington Department of Transportation, counties, Fort Lewis, and McChord AFB to minimize road-kill mortality. Use road closures where possible, controlled access, signing, reduced speed limits and squirrel bridges to provide safe passage for squirrels across roads and reduce the likelihood that vehicles will kill squirrels on roads. A squirrel bridge has been successfully used for eastern gray squirrels in Longview, Washington, and needs to be evaluated for potential use by western gray squirrels.

2.2.2 Minimize accidental and illegal killing of western gray squirrels.

Accidental and illegal shooting of western gray squirrels is not known to be a significant source of mortality, but incidents should be documented to help determine if additional education or local enforcement is needed. Shooting mortality may be a significant problem on public lands where western gray squirrel co-occur with California ground squirrels.

2.2.3 Conduct limited local control of eastern gray or fox squirrels if necessary.

Where eastern gray squirrels or fox squirrels are invading occupied western gray squirrel habitat or habitat where a reintroduction is planned, there may be a need for measured control.

2.2.4 Work with the WDFW Game Division to prevent potential conflicts with turkey management.

Unless research determines that turkeys do not affect squirrel populations, prevent translocations of turkeys to locations where squirrels could be affected. Should research indicate competition is important, adjust turkey harvest to reduce conflicts with squirrel recovery.

2.3 Protect western gray squirrels from disturbance.

2.3.1 Identify human-related disturbance factors and limit impacts in occupied squirrel habitat.

While it may not have a major impact to squirrel populations, disturbance to western gray squirrel nesting and foraging may result from noisy activities, logging, unleashed pets, recreational development, or repeated disruption of the forest understory where squirrels search for food. If areas are identified where humans and their pets seriously inhibit nesting or foraging, work with landowners and recreationists to minimize and mitigate impacts through habitat restoration, management plans and recreation planning.

3. Augment existing populations and establish new populations.

3.1 Develop and implement an augmentation plan for the Puget Trough western gray squirrel population.

3.1.1 Develop an augmentation plan for the Puget Trough.

Assess habitat capability for increasing and maintaining the Puget Trough population through augmentation. Develop an augmentation plan in cooperation with personnel from Fort Lewis and McChord AFB for the existing population. The plan should include the number, timing, and sources for squirrels, monitoring and a detailed analysis of threats and available habitat and habitat capability to determine the expected results and likelihood of success. Use the results of genetic analysis (task 6.3.1) to identify the most appropriate source population(s) and determine if the source population(s) can safely withstand removal of a sufficient number of individuals.

3.1.2 If determined to be feasible, translocate western gray squirrels to the Puget Trough.

3.1.3 Monitor the survival and productivity of released individuals.

Monitor released individuals with radio telemetry, tagging, and trapping as needed to assess survival. Monitoring should be intensive enough to be able to identify the reasons for project success or failure.

3.2 Determine whether other areas are in need of augmentations or reintroductions.

3.2.1 Evaluate the feasibility and need for augmenting populations in the South Cascades and North Cascades Recovery Areas.

The population on the Yakama Reservation and in the Stehekin Valley may warrant genetic evaluation to determine if they are isolated and in need of population augmentation to improve genetic diversity.

3.2.2 Evaluate the feasibility and need for reintroductions in other parts of the historic range of western gray squirrels in Washington.

The Oak Creek and Wenas wildlife areas should be evaluated with a reintroduction feasibility study; potential problems to be addressed would be the potential for mortality from shooting when mistaken for California ground squirrels. Successful reintroductions of the endangered Delmarva fox squirrel (*Sciurus niger cinereus*) in Maryland provide some information on methods and needed number of squirrels (Therres and Willey 2002, Lance et al. 2003).

3.3 Conduct augmentations or reintroductions as needed.

3.3.1 Develop augmentation/reintroduction plans for local areas where needed.

3.3.2 Conduct translocations of squirrels.

3.3.3 Monitor the survival and productivity of released and resident individuals and evaluate the success of the project.

4. Protect western gray squirrel habitat.

4.1 Develop and refine statewide maps of suitable habitat within the western gray squirrel range in Washington.

The existing statewide map of vegetation types that may contain western gray squirrel habitat was based on simple models at a gross scale; a finer scale map that includes measures of habitat condition needs to be developed for recovery areas, particularly the North Cascades, and the map of suitable habitat in the Klickitat needs to be further refined. Data on oak-conifer habitat on the Yakama Reservation and the remainder of the South Cascades Recovery Area needs to be added to maps of suitable habitat. This would help identify habitat that should be surveyed or evaluated for potential reintroductions and/or habitat restoration.

4.1.1 Develop and implement standardized methods to map suitable western gray squirrel habitat.

Develop statistically rigorous sampling protocols to refine the current understanding of habitat needs to be able to characterize optimal and marginal habitats.

4.1.2 Analyze current habitat conditions in recovery areas.

Analyze habitat condition in areas targeted for recovery starting with occupied areas, and working outward to adjacent areas intended for connecting populations. A Habitat Suitability Index model or other model could be developed, tested, and used to evaluate habitat. Identify how and where habitat conditions lack important features such as mature pines, Douglas-fir, and oaks and an open understory, and where substantial habitat losses are occurring. Actions to restore critical features should be included in forest and fire management planning.

4.1.3 Develop a process to obtain information on land use and habitat alteration within the western gray squirrel recovery areas and regularly update maps.

4.2 Facilitate western gray squirrel habitat protection on state and private land during timber harvest operations.

4.2.1 Work with landowners to develop habitat protection measures that consider the needs of western gray squirrels during timber harvest and road building.

Work with landowners to protect large mast-producing pine and oaks, oaks of a range of ages for recruitment, and especially trees with cavities. Encourage maintaining canopy connections (branches within 1 m) through clumping and retention of stringers.

4.2.2 Evaluate the current guidelines and process of protecting western gray squirrels and habitat during forest practices.

Current guidelines for protection of western gray squirrel habitat on state and private lands rely on landowner agreements to apply western gray squirrel guidelines for individual timber harvest activities. These need to be evaluated to determine if they are successfully protecting western gray squirrel habitat values. The guidelines may need to be revised to take into account recent research on squirrels and habitat.

4.2.3 Explore alternative ways and incentives for preserving and enhancing western gray squirrel habitat values on state and private timberlands.

Work with landowners and other interested parties to explore options and alternatives to protect western gray squirrel habitat values during timber harvest operations.

4.2.4 If a critical habitat protection rule is needed, work with the state Forest Practices Board to develop a rule proposal for western gray squirrels, and develop strategies needed for landowner habitat management plans.

Determine if a forest practice critical habitat rule specific to western gray squirrels that applies statewide is needed. If a rule is adopted, landowners have the option of developing Special Wildlife Management Plans for western gray squirrels that apply to harvest activities on their ownership. Approved plans would exempt landowners from a critical habitat rule. Work with interested landowners on developing a landscape approach that could be incorporated into habitat management plans.

4.3. Work with counties and cities to protect western gray squirrel habitat on private lands.

Provide counties with maps that identify western gray squirrel occurrences and habitat. Encourage clustering of houses in openings and recommend measures to protect the patch size and integrity of native oak-pine forest, and to control conifer encroachment and development of overly dense stands.

4.3.1 Provide technical assistance to counties and cities for the development and implementation of Critical Area Ordinances and community and open space planning efforts to minimize the effects of development on western gray squirrel habitat.

Review and comment on proposed revisions of critical area and clearing and grading ordinances. Encourage counties to adopt clear standards of protection for oak woodlands and western gray squirrel habitat.

4.3.2 Provide timely review of project applications that affect western gray squirrel habitat.

Continue to provide technical assistance during the review of development proposals and mitigation plans.

4.3.3 Work with private landowners to minimize impacts to western gray squirrel habitat from home construction and other development in rural areas.

4.4 Protect habitat by reducing the risk of catastrophic wildfires.

Not all western gray squirrel habitat is at high risk for wildfire, but where the risk of stand replacing wildfires is high, fuel treatments should be applied to reduce the intensity and rate of spread should a fire occur. Covington et al. (1997) found that prescribed burning without thinning or manual fuel removal resulted in high mortality of old ponderosa pines. Harrod et al. (2007a, b) report that a combination of thinning and late-season burns holds the most promise for restoring historical structure of ponderosa pine forests. Fuel loads can be reduced by thinning overstocked stands, hand cutting, removal of dense underbrush, and removing duff around large trees. Management of occupied habitat should be done carefully to avoid excessive disturbance during nesting and the creation of unsuitable conditions. Plan treatments with variable density thinning, retention of large trees, and to promote canopy clumpiness and interlocking canopy crowns to improve squirrel habitat, as Dodd et al. (2003) recommended for Abert's squirrel. Hamer et al. (2005) noted that western gray squirrels in the Stehekin Valley did not seem to avoid or select for locations that had been prescribed burned.

4.4.1 Reduce crown fire risk on WDFW lands and encourage appropriate fire management measures on other public lands.

4.4.2 Work with owners of private lands near and adjacent to WDFW lands, and other public lands essential to western gray squirrels, to maintain squirrel habitat value while reducing risk of crown fires. [Information on federal grants for fuels reduction and for developing county-wide Community Wildfire Protection Plans can be found at: http://www.nwfireplan.gov/CommunityAsst/Apply.htm]

4.5 Protect essential squirrel habitat through easements, cooperative agreements, and acquisitions.

4.5.1 Use conservation easements and cooperative agreements to protect western gray squirrel habitat.

The Nature Conservancy and WDFW have used conservation easements effectively to protect and manage blocks of private land, while maintaining the integrity of human communities. This approach to habitat protection and management should be considered for its potential to protect large blocks of contiguous western gray squirrel habitat. Cooperative agreements may also be used to develop management and protection strategies for western gray squirrel habitat.

4.5.2 Consider acquisitions of important habitat if there are willing sellers.

Where there are willing sellers, consider acquisition of important parcels of squirrel habitat. Facilitate protection and management by adding them to conservation lands, such as county land trusts, The Nature Conservancy, state research natural areas and natural area preserves, and state wildlife areas.

4.6 Protect western gray squirrel habitat on federal and tribal lands.

4.6.1 Work with tribes, DOD (Fort Lewis) and the U.S. Forest Service to protect western gray squirrel habitat.

5. Enhance western gray squirrel habitat.

Mixed hardwood-conifer habitats, particularly those comprised of ponderosa pine and oak, may require management through timber harvest or natural disturbance in order to produce large, healthy trees and abundant mast. Habitat capability could be improved by commercial and precommercial thinning of stagnant, overstocked stands, harvest of Douglas-fir and true fir where they encroach on stands of oak and pine, planting of native mast-bearing trees and shrubs, and removing invasive trees and shrubs. Nest searches should be conducted prior to timber harvest so nest trees are not inadvertently cut or damaged by the felling of nearby trees. Changes in habitat structure and composition also have the potential to allow invasion by exotic species, including eastern gray squirrels and Scot's broom. Non-native trees and shrubs should be discouraged as potential carriers of disease and insects. The health of native mast-producing trees should be monitored for signs of stress that could contribute to crop failures, and for signs of exotic and debilitating outbreaks of insects and disease (e.g., sudden oak death syndrome). Where smoke and fire does not pose excessive risk to human health or buildings, prescribed burns can be used in conjuction with fuel reduction to improve forest health. Burns should be planned to minimize impact on western gray squirrels. For example, prescribed burns conducted in the spring could reduce food availability when females are pregnant or lactating and smoke could affect juveniles still in the nest. Harrod et al. (2007b) found spring burns were not as effective at reducing fuel loads.

5.1 Enhance squirrel habitat on WDFW lands.

5.1.1 Analyze current habitat conditions on WDFW lands and develop management plans to improve conditions where needed.

Include western gray squirrel habitat enhancement whenever management plans are written or revised for WDFW-owned lands that have western gray squirrel habitat and are within the recovery area. Strategies might include treatments to improve forest stand conditions for pine and oak, to improve connectivity or to increase the diversity and abundance of food sources. Tasks potentially needed include facilitating access to water with canopy connections, protecting riparian zones from livestock and wintering concentrations of elk, planting pines, oaks or other native mast-bearing trees and shrubs, using prescribed fire, pre-commercial thinning, or select-cut harvest to remove excess conifer regeneration and encroaching Douglas-fir and other species that are favored as a result of historical grazing and fire exclusion.

5.1.2 Seek grants and partnerships for habitat restoration and enhancement.

5.1.3 Implement habitat enhancement through logging contracts, volunteer and conservation corps workers as funds allow.

5.2. Facilitate western gray squirrel habitat enhancement on other public lands.

5.2.1 Work with WDNR and the U.S. Forest Service to restore healthy oak-conifer habitat and maintain western gray squirrel habitat values while reducing the risk of stand replacing wildfires in the Klickitat and Okanogan regions.

5.2.2 Work with the Department of Defense (Fort Lewis), the Nature Conservancy, and Thurston County on habitat restoration and enhancement on county, Fort Lewis, and Nature Conservancy lands.

Forest land otherwise managed for spotted owl on Fort Lewis could be managed to produce stand characteristics desirable for western gray squirrels. This could include promoting large wolf trees for den sites, creating multi-branched conifers for nesting, increased attention to crown connectivity and variable stand density.

5.2.3 Work with McChord AFB to develop a long-term strategy for the management and restoration of oak-conifer habitat.

Squirrel habitat on McChord AFB would benefit from plans for oak woodland and western gray squirrel management like the plans developed for Fort Lewis. Plans should include detailed management recommendations and protocols for monitoring changes in vegetation and squirrel populations.

5.2.4 Facilitate information exchange with the Yakama Nation concerning management and restoration of oak-conifer habitats on the reservation.

5.2.5 Work with the Bureau of Land Management and U.S. Fish and Wildlife Service to develop management and restoration plans for western gray squirrels on their lands in the recovery area.

5.2.6 Seek funding for habitat management for western gray squirrels on other conservation lands.

5.3 Encourage and facilitate habitat enhancement on private lands.

Provide technical assistance to private landowners interested in protecting western gray squirrel habitat values and managing oak woodlands. Facilitate grant applications for projects to enhance western gray squirrel habitat through conservation programs such as the Landowner Incentive Program, Wildlife Habitat Incentives Program, and the Private Stewardship Grants Program. Washington Department of Natural Resources's Forest Landowner Stewardship Program can assist small private landowners in developing management plans. WDFW and other groups should work to encourage small, private landowners to develop management plans that include restoration and habitat enhancement projects that would be beneficial to western gray squirrels. Such projects may also provide additional benefits to landowners including fire control, aquifer recharge, wildlife value, and land value.

5.4 Develop a landscape level approach to habitat management.

Landscape-scale plans for improving habitat condition and connectivity would help ensure suitable conditions into the future. Agreements or management plans to protect nesting and foraging habitat and movement corridors should promote the production of mature trees of large-seeded, mast-producing species such as ponderosa pine and Oregon white oak and minimize disturbance of the ground surface to promote the production of hypogeous fungi.

6. Conduct research necessary to conserve and restore western gray squirrel populations.

6.1 Research and evaluate methods that can be used to monitor western gray squirrel populations.

Research may be required to determine which sampling methods are most effective. A different methodology may be needed in each region due to differences in habitat and confounding factors such as eastern gray squirrel presence. Nest condition, snow tracking, hair snag, visual and camera survey methods should be evaluated, along with other methodologies that may be used effectively.

6.2 Conduct research to improve understanding of western gray squirrel life history, limiting factors and habitat needs and the effect of timber harvest, development, and habitat change on habitat quality and populations.

6.2.1 Determine the most important factors limiting western gray squirrel populations in Washington.

Limiting factors likely vary among the three regions within the western gray squirrel recovery area. Studies need to be conducted in each area to determine operative factors and influences on reproduction, recruitment, survival, dispersal, and mortality.

6.2.2 Investigate the effects of timber harvests on western gray squirrel populations.

Test the effects of a range of forest management prescriptions on squirrel populations and habitat to determine thresholds of effects. Work with local timber companies, the U. S. Forest Service, and others that might be interested in a cooperative study.

6.2.3 Determine if there is competition occurring with California ground squirrels, or introduced eastern gray squirrels, fox squirrels, and wild turkeys, and if so, evaluate the impacts to western gray squirrel populations.

Investigate the extent that the preferred foods and habitat of the introduced species and California ground squirrels overlap those of western gray squirrels. Compare the habitat use and demographics of western gray squirrels present in areas with and without introduced populations to determine if competitive interactions are affecting western gray squirrel populations or distribution. Characterization of the preferred habitat of introduced species and identifying habitat management practices to reduce their co-occurrence with western gray squirrels would also be useful.

6.2.4 Investigate the diet of western gray squirrels in Washington and determine factors affecting food availability.

Fecal analysis, observational, and quantitative studies should be conducted to determine if and how food quality and quantity may limit western gray squirrel populations in Washington. Identify dietary preferences, quantify food availability and determine the relationship between diet and reproductive success.

6.2.5 Investigate the effects of fire management, understory treatment, and habitat restoration on diet, dispersal, home range size, habitat use, reproduction and recruitment of western gray squirrels.

6.2.6 Develop region-specific habitat suitability models that would be useful for guiding timber harvest and habitat restoration actions.

6.3 Investigate the demographics, genetics and population dynamics of western gray squirrels in Washington.

6.3.1 Develop microsatellite markers and conduct needed genetic analysis of western gray squirrel populations to facilitate selection of appropriate source populations for translocations and the use of DNA for demographic monitoring.

6.3.2 Investigate demography, genetics and dynamics of western gray squirrel populations to inform minimum viable population estimates and models of extinction risks.

6.3.3 Investigate the role of notoedric mange in western gray squirrel population fluctuations and conditions that may contribute to the incidence and severity of outbreaks.

6.4 Investigate the feasibility and effectiveness of treating western gray squirrels for mange.

6.4.1 Evaluate the safety, feasibility, and effectiveness of available mange treatments for western gray squirrels captured during research and translocations.

6.4.2 Evaluate whether it is advisable and effective to treat selected local squirrel populations during mange outbreaks.

It may be possible to mitigate the effects of mange on local populations of squirrels, such as those on Klickitat Wildlife Area and where they have been reintroduced, using topical treatments on captured squirrels or by distributing treated food items. However, from a natural selection standpoint, it may not be desirable to prevent the disease from eliminating the most susceptible individuals.

6.5 Develop translocation methods for western gray squirrels.

6.5.1 Evaluate protocols for the capture, transport, and release of western gray squirrels.

7. Review and revise recovery and conservation planning documents for western gray squirrel populations in Washington.

7.1 Estimate a minimum viable population of western gray squirrels.

When sufficient data is available on western gray squirrel demography, genetics, and population dynamics, revise/update estimates of minimum viable population.

7.2 Revise recovery objectives and strategies for the western gray squirrel as needed.

Use research results and new information to update and revise the western gray squirrel recovery plan.

8. Coordinate and cooperate with other agencies, landowners and private groups in the conservation, protection, and restoration of the western gray squirrel in Washington.

8.1 Form working groups in the 3 regions to implement recovery actions for western gray squirrels.

8.2 Participate in the development of a prairie and oak woodland candidate conservation agreement in the south Puget Sound region and other cooperative planning efforts.

A candidate conservation agreement with the U.S. Fish and Wildlife Service is being developed for management of prairie and oak woodland with multiple partners, including Fort Lewis, WDFW, Port of Olympia, TNC, and others. A formal candidate conservation agreement provides the Service some certainty about conservation measures undertaken by landowners for consideration during future listing decisions, while providing the landowners assurances that should the species be listed, no additional conservation measures will be required of them.

8.3 Work with the Yakama Nation, Fort Lewis, county governments, and other jurisdictions to protect known populations of western gray squirrels, and to achieve changes in habitat composition, structure, and function that will result in improved habitat conditions for squirrels.

8.4 Work with the U.S. Forest Service, as feasible, during implementation of the "dry forest strategy" to achieve changes in habitat composition, structure, and function that will result in improved habitat conditions for squirrels.

The dry forest strategy developed by the U.S. Forest Service could improve conditions for squirrels on federal forestlands in the Okanogan if the species is included in Forest Management Plans and it is implemented in a manner sensitive to the needs of western gray squirrels.

8.5 Secure funding for recovery activities.

8.6 Provide technical review of Special Wildlife Management Plans and other plans that include coverage for the western gray squirrel.

There may be opportunities to work with private companies on western gray squirrel management plans, particularly if a state Forest Practices critical habitat rule is adopted by the Forest Practices Board. Special Wildlife Management Plans (WAC 222-16-080, Sect. 6C) for western gray squirrel protection are an option for landowners that would exempt the covered lands from the critical habitat rule. Large timber companies may develop Habitat Conservation Plans for federally listed or candidate species may present an opportunity to improve squirrel habitat.

9. Develop public information and education programs.

9.1 Initiate a squirrel identification and data collection project.

9.1.1 Train biologists and volunteers in squirrel identification, survey methods, data collection and reporting to assist in survey and monitoring efforts.

9.1.2 Expand data collection efforts and minimize incidental hunting mortality by providing identification and reporting materials to hunters.

Hunters trained in squirrel identification could contribute to data collection and monitoring efforts by reporting the location of western gray squirrels observed while in the field.

9.2 Develop an education and outreach strategy to gain support for western gray squirrel recovery.

Resources should address species identification, habitat and management conflicts, opportunities for habitat enhancement, the influence of exotic species (e.g. eastern gray and fox squirrels) and supplemental feeding, habitat loss and degradation, and other threats.

9.2.1 Develop and disseminate information, education and interpretation materials.

One interpretive sign and one pamphlet were produced by WDFW to raise awareness and assist in identification of western gray squirrels. Production and dissemination of information and education materials should be expanded. The Forest Service and BLM have produced guides to restoring oak habitats (Vesely and Tucker 2005, Harrington and Devine 2006). Video or audio messages may help to inform and encourage public cooperation and acceptance of recovery activities.

9.2.2 Develop educational materials on squirrel identification, conservation, and habitat management.

Materials should be designed for at least two target audiences, including landowners and school-aged children in squirrel population areas.

9.2.3 Develop and disseminate materials about the negative consequences of transporting and releasing or feeding eastern gray and fox squirrels on western gray squirrels.

Potential partnerships include parks and recreation departments in regions where western gray squirrels are found.

9.2.4 Identify media sponsors and public outreach and education partners to increase public knowledge and cooperation with recovery actions.

9.3 Periodically update and revise WDFW's Priority Habitats and Species (PHS) management recommendations for the western gray squirrel.

PHS recommendations represent "best management practices" used to protect western gray squirrel habitat. These were last published by WDFW in 1991 and they need to be updated. Recent and ongoing research should be used to periodically update these recommendations to promote good stewardship of western gray squirrels and their habitat.

9.4 Conduct workshops for public and private land managers on habitat management and enhancement of pine and oak forests and woodlands to benefit western gray squirrels.

WDFW sponsored an Oregon white oak conference in 2003 that was well attended. Similar workshops for land managers could benefit management initiatives on public and private lands within the western gray squirrel recovery area.

IMPLEMENTATION SCHEDULE

Identified below are the agencies, WDFW involvement, task priorities, and estimates of annual expenditures needed for western gray squirrel recovery (Table 13). Cost estimates do not mean that funds have been designated or are necessarily available to complete the recovery tasks. The following conventions are used:

Priority 1 Actions needed to monitor the population and prevent the extinction of the species in Washington.

Priority 2 Actions to prevent a significant decline in population size or habitat quality, or some other significant negative impact short of extirpation.

Priority 3 All other actions necessary to meet recovery objectives.

Acronyms for other landowners and agencies are:

DFW Washington Department of Fish and Wildlife
DOD U. S. Department of Defence
DOT Washington Department of Transportation
DNR Washington Department of Natural Resources
FS USDA Forest Service
FWS USDI Fish and Wildlife Service
PL Private landowners (e.g. large timber companies as well as ranchers and smaller forest landowners, etc.)
YN Yakama Nation

Implementation of recovery strategies is contingent upon availability of sufficient funds to undertake recovery tasks.

Table 13. Implementation schedule and preliminary cost estimates for implementation of the Washington Recovery Plan for the Western Gray Squirrel

	Recovery Task	Duration	Potential Cooperators	Est. Annual	DFW
	1.1 Monitor status of known populations	ongoing	DFW, DOD, FS, FWS, PL	60	40
	1.2 Survey suitable habitat to better define distribution	5	DFW, FS, YN, PL	15	12
	1.3 Facilitate cooperative surveys, monitoring	5	DFW, YN	5	3
	2.1 Identify mortality factors for local populations	3	FS, DOD, FWS	20	10
	2.2 Reduce sources of mortality and competition	3	DFW, DOT	20	10
	2.3 Protect western gray squirrels from disturbance	ongoing	DFW,	5	5
	3.1 Develop plan and implement Puget Trough augmentation	5	DFW, DOD,	50	25
	3.2 Identify other areas where augmentation/reintroduction is feasible	cyclic	DFW,YN, FS	10	8
	3.3 Conduct translocations as needed	10	DFW, FS, YN	40	35

	Recovery Task	Duration	Potential Cooperators	Est. Annual	DFW
	4.1 Develop and refine suitable habitat maps	2	DFW, FS, DOD, YN	15	5
	4.2 Protect habitat on state and private lands during timber harvest	ongoing	DFW	30	30
	4.3 Assist implementation of county ordinances	ongoing	DFW	5	5
	4.4 Protect habitat from wildfires	5	DFW, DNR, FS	Tbd[c]	-
	4.5 Protect habitat with easements, agreements, acquisitions	ongoing	DFW, DOD, FWS	Tbd	-
	4.6 Protect squirrel habitat on federal and tribal lands	ongoing	DFW, FS, YN, DOD	Tbd	10
	5.1 Enhance habitat on WDFW lands	ongoing	DFW	Tbd	-
	5.2 Facilitate habitat enhancement on other public lands	ongoing	DFW, DOD,FS, YN, FWS	Tbd	-
	5.3 Facilitate habitat enhancement on private lands	ongoing	DFW,PL	Tbd	-
	5.4 Develop landscape approach to habitat management	1	DFW	Tbd	80
	6.1 Research methods for survey and monitoring	2	DFW, FS	35	25
	6.2. Research life history, habitat needs, and management effects	10	FS, DFW, DNR, PL	100	75
	6.3 Investigate demographics, genetics, and population dynamics	10	DFW, FWS	12	4
	6.4 Investigate feasibility of treating squirrels for mange	3	DFW	20	20
	6.5 Develop methods of squirrel translocation	5	DFW	5	5
	7.1 Estimate minimum viable population, when possible	1	DFW	1	1
	7.2 Revise recovery plan as needed	1	DFW	20	20
	8.1 Form and facilitate working groups to implement recovery actions	2	DFW, DOD, FS, PL	15	10
	8.2 Participate in interagency conservation planning for oak woodland	1	DFW, DOD, FWS	20	5
	8.3 Work with Ft.Lewis, Yakama Nation, counties to protect/improve habitat	ongoing	DFW	5	5
	8.4 Work with Forest Service on dry forest implementation	5	WDFW,FS	2	1
	8.5 Secure funding for recovery activities	ongoing	DFW,DOD, YN,FWS	5	3
	8.6 Review Special Wildlife Management Plans, HCPs and other plans	5	DFW, PL, DNR	30	10
	9.1 Initiate an identification/data collection program	ongoing	DFW, FS	4	2
	9.2 Develop education and outreach strategy and materials	2	DFW	2	2
	9.3 Revise PHS management recommendations for squirrels	1	DFW	2	2
	9.4. Conduct habitat management workshops for land managers	1	DNR, DFW, FS, PL	10	6

[a]Anticipated DFW share of cost if funds are available.
[b]Estimated total cost for 5-year period, assuming all tasks initiated during period. Some tasks may not to be needed.
[c]Cost estimate to be determined.

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Appendix A. Historical western gray squirrel records from Washington, 1897 – 1975.

No.	County	Year	Location	Collector or source	Specimen/record type	Museum[a]
1	Klickitat	1897	Cleveland	Fisher, W.K. and J.A. Loring	2 F, skin and skull	USNM
2	Klickitat	1897	Cleveland	Bailey, V., Loring, J.	1 M, 1 F, skin and skull	USNM.
3	Klickitat	1897	Trout Lake	Loring, J.A.	3 F, 2 M; skin and skull.	USNM.
4	Yakima	1905	Mt. Adams	Jewett, S.G.	1M, skin and skull	USNM
5	Pierce	1908	Tacoma	Bowles, J.H.	Skin and skull	USNM
6	Klickitat	1917	Outlet Falls	Shaw, W.T.	1 M, skin	CM
7	Klickitat	1917	White Salmon	Taylor, W.P.	Skin and skull	USNM
8	Pierce	1917	Puyallup	Cantwell, G.G.	M, skin and skull	USNM
9	Chelan	1918	Manson	Williams, E.	M, skin and skull	USNM
10	Klickitat	1918	White Salmon	Cantwell, G.G.	M, skin and skull	USNM.
11	Klickitat	1918	Liberty Bond, 12 mi N of Lyle	Cantwell, G.G.	2 M, skin and skull	USNM.
12	Chelan	1921	Lakeside	Fulkerson, R.C.	Skin and skull	USNM
13	Thurston	1923	Olympia	Couch, L.K.	F, skin and skull	USNM
14	Thurston	1924	Olympia	Couch, L.K.	F, skin	USNM
15	Pierce	1930	Roy	Scheffer, T.H.	F, skin and skull	USNM
16	Pierce	1930	Roy	Scheffer, T.H.	M, skin and skull	USNM
17	Pierce	1936	Spanaway	Brown, D.E.	F, skin and skull, #15079	BM
18	Pierce	1938	Spanaway Lake	Lerass, H.J.	M, skin and skull, #13859	BM
19	Skamania	1938	Underwood	Johnson, M.L.	F, skin and skull; skull crushed,#656	UPS
20	Kittitas	1938	Liberty	Bryant, F., (Scheffer 1957)	observations	
21	Chelan	1938	Cashmere	McFarland, C.		
22	Chelan	1938	Cashmere	McFarland, C. (Scheffer 1957)		
23	Klickitat	1938	3-6 mi E of Underwood	Johnson ML (Scheffer 1957)		
24	Pierce	1939	Edgewood	Slipp, J.W.		UPS
25	Pierce	1939	Orchard Pond, Ft. Lewis	Cheney, P.W.	1 M, #782	UPS
26	Klickitat	1939	Little Klickitat, 6 mi NE of Goldendale	Scheffer, V.B.	F, skin and skull	USNM.
27	Chelan	1939	Dryden	Orcutt, H., (Scheffer 1957)	verbal account and tracks in snow Jan 1939	
28	Klickitat	1939	Wilson Charley Canyon	Scheffer, V.B.	3 mi S of Satus Pass	
29	Pierce	1939	W Gravelly Lake	unknown		
30	Yakima	1940	Tampico	Thornton, J. comm.to L. Stream	sightings, late 1940s - early 50'S	
31	Pierce	1941	Tacoma	Palmer, D.D.	F, skin and skull, #12275	BM
32	Pierce	1947	N. Puyallup	Scheffer, T., P.W Cheney	Shot in walnut orchard	
33	Pierce	1950	American Lake	Kiser, B.	2 skins#633, 635.	UPS
34	Yakima	1950	Ahtanum Guard Station	Mondor, B. (Stream 1993)	Observed, 1940'S and 1950'S	
35	Pierce	1950	26TH and Washington, Tacoma	Johnson, M.L.		
36	Pierce	1950	American Lake	Durham	Spec.MLJ 1248	UPS?
37	Pierce	1951	Spanaway	Johnson, M.L.	2 M, 1 F, skins/skulls #3147-3149	UPS
38	Pierce	1951	Spanaway	Johnson, M.L.	3 juv. M, 1ad. M, 1ad F; skins/skulls#2804-2808	UPS
39	Pierce	1951	Spanaway	Johnson, M.L.	1 M, 2 F, skins and skulls #2682, 2683, & 2684	UPS

No.	County	Year	Location	Collector or source	Specimen/record type	Museum[a]
40	Pierce	1951	Spanaway	Johnson, M.L. (from Denny)	Spec# MLJ1272,	[UPS?]
41	Pierce	1952	Spanaway	Johnson, M.L.	F, skin and skull	CM
42	Thurston	1956	Waldrick Rd betw Offut & McIntosh Lks.	Shultz, D		
43	Chelan	1960	Swakane Canyon	USFS Wenatchee NF files		
44	Chelan	1964	Eagle Creek	Patterson, J. (Barnum 1975)		
45	Chelan	1964	Ribboncliff Canyon	Patterson, J. (Barnum 1975)		
46	Kittitas	1966	Tarpiscan Creek	Patterson, J. (Barnum 1975)		
47	Chelan	1966	Purtteman Gulch	Patterson, J. (Barnum 1975)		
48	Chelan	1966	Swakane Canyon	Patterson, J. (Barnum 1975)		
49	Chelan	1966	Tumwater Canyon	Patterson, J. (Barnum 1975)		
50	Yakima	1967	Ahtanum	Howe, B., E. Bowhays files	1 indiv. seen	
51	Chelan	1967	Sunnyslope	Patterson, J. (Barnum 1975)		
52	Chelan	1967	Byrd Canyon	Patterson, J. (Barnum 1975)		
53	Chelan	1967	Steiliko Canyon	Patterson, J. (Barnum 1975)		
54	Chelan	1968	Grade Creek	Patterson, J. (Barnum 1975)		
55	Chelan	1969	Stehekin Rd, 2.0 km NW of Harlequin Bridge	Wills, H., Nat'l Park Service		
56	Chelan	1969	Stehekin Ranger Station	National Park Service		
57	Chelan	1969	Sanders Canyon	Patterson, J.		
58	Chelan	1969	Roaring Creek	Barnum (1975)		
59	Okanogan	1969	Gold Creek	Barnum (1975)		
60	Chelan	1969	Manson-Antilon Lake	Patterson, J. (Barnum 1975)		
61	Okanogan	1969	Early Winters Creek	Barnum (1975)		
62	Chelan	1969	Knapp Coulee	Patterson, J. (Barnum 1975)		
63	Chelan	1969	Johnson Creek	Patterson, J. (Barnum 1975)		
64	Okanogan	1969	Libby Creek	Barnum (1975)		
65	Okanogan	1969	Buttermilk Canyon	Barnum (1975)		
66	Pierce	1969	McKenna	Smallwood, G., WDG.		
67	Okanogan	1970	Rat Lake	Barnum (1975)		
68	Okanogan	1970	Brewster	Barnum (1975)		
69	Pierce	1972	Harts Lake Rd	Allen, E.	1 M, skin and skull#28298	UPS
70	Yakima	1972	3 mi up Cowiche Crk from Naches R.	Carter, M. to E. Bowhays	1 observed	
71	Yakima	1972	Naches R., 2 mi above mouth Cowiche Crk	Kidd, A., E. Bowhays files.	1 observed	
72	Okanogan	1972	Lower Black Canyon			
73	Pierce	1972	Nisqually R. on Military Rd	Mericle, E		
74	Pierce	1972	Ft Lewis Golf Course	Mericle, E		
75	Thurston	1972	Fiander Lk, Ft Lewis	Mericle, E.		
76	Thurston	1972	Rochester	Brent, H.		
77	Pierce	1972	Chambers Creek Rd	Swanson C., WDG (Barnum 1975)		
78	Pierce	1972	S Tacoma Game Farm	Angerman B.	Observed spring, summer	
79	Thurston	1972	McAllister Springs	Zimmerman D. (Barnum 1975)		
80	Thurston	1972	Gate	C. Swanson (Barnum 1975)		
81	Thurston	1972	Lake St. Clair	Barnum (1975)		
82	Okanogan	1972	Shular Rd, Black Cyn	Marr, N. WDG	Seen 1972; 2 indiv 1979	
83	Okanogan	1972	Black Canyon Crk	R. Brady, (WDG 1978)		

No.	County	Year	Location	Collector or source	Specimen/record type	Museum[a]
84	Pierce	1973	Pt. Defiance Park	Roache, B.C.	1 M, skin and skull,#28299.	UPS
85	Okanogan	1973	0.5 mi S of mouth Gold Creek, Methow Valley	Demiter, J.	F, skin	CM
86	Chelan	1973	Rainbow Falls, Stehekin R. Valley	WASEM, R - NPS		
87	Chelan	1973	Rainbow Falls	North Cascades Nat'l Park (Barnum 1975)	Tracks seen	
88	Grays Harbor	1973	Central Park area.	Brent, H.	observed	
89	Grays Harbor	1973	Oakville	Barnum (1975)		
90	Chelan	1973	Oklahoma Gulch nr Chelan	WDG 1973	Remnant population	
91	Yakima	1974	Tieton River	Schrindel, G. (Stream 1993)	Road kill	
92	Yakima	1974	1 mi below conflu. S and M Fork Cowiche Crk	Scherer, R & L. Konen, WDW	1 observed	
93	Yakima	1974	1 mi E Trout Lodge	Harber, F., E. Bowhay files	Road kill	
94	Pierce	1974	Ft. Lewis	Ft Lewis staff	1 indiv	
95	Pierce	1974	Ft. Lewis	Ft Lewis staff	2 indiv	
96	Pierce	1974	Ft. Lewis	Ft Lewis staff	5 indiv	
97	Pierce	1974	Ft. Lewis	Ft Lewis staff	8 indiv	
98	Okanogan	1974	1.5 mi N of Alta Lake	Demiter, J #74-146	1 F	
99	Thurston	1974	2 mi N of Tenino,RR pass on Old 99	Thorniley, M. WDG	Seen for past 20 years	
100	Chelan	1974	25-Mile Creek	J. Patterson (Barnum 1975)	Regularly observed	
101	Thurston	1974	Waldrick Rd	Barnum (1975)		
102	Chelan	1975	Stehekin Rd about 0.4 km N of Rainbow Crk.	Wasem, R – Nat'l Park Service		
103	Thurston	1975	Ft. Lewis	Ft Lewis staff	1 indiv	
104	Pierce	1975	Ft. Lewis	Ft Lewis staff	1 indiv	
105	Pierce	1975	Ft. Lewis	Ft Lewis staff	1 indiv	
106	Pierce	1975	Ft. Lewis	Ft Lewis staff	3 indiv	
107	Pierce	1975	Ft. Lewis	Ft Lewis staff	4 indiv	
108	Pierce	1975	Ft. Lewis	Ft Lewis staff	6 indiv	
109	Pierce	1975	Ft. Lewis	Ft Lewis staff	7 indiv	
110	Yakima	1975	Toppenish Crk Steep Canyon, elev. 1600 ft	Laumeyer, P USFWS	15-20 indiv.	
111	Pierce	1975	Western State Hospital	Chappell, C	Also seen 8-8-72.	

[a]Museum abbreviations: USNM = U. S. National Museum, Smithsonian Institution; CM = Conner Museum, Washington State University, Pullman; BM = Burke Museum, University of Washington, Seattle; UPS = Slater Museum, University of Puget Sound, Tacoma.
[b] M= male, F= female, Numbers are museum specimen numbers.

Appendix B. Desirable characteristics of western gray squirrel habitat in eastern and western Washington.

Habitat Characteristic and basis or explanation[a]
Eastern Washington
1) Ponderosa pine dominated stands with 360-685 trees per hectare (145-277 tpa), including 31-223 tph (13-81 tpa) of oaks, where present, and not more than 15-20% fir. *This is from the means +/- 1 SD in Linders (2000). Gregory reported 432 tph in nest plots; a lower range of stem density that includes more large trees (12-36 inches) may actually be preferable; although Keith (2003) also suggests a similar density of 300-600 tph mostly >30cm dbh for Abert's squirrel in Arizona.*
2) Basal area of > 23 m^2/ha (100 ft^2/ac). *This is the mean BA for core areas, the upper end of a range of good habitat is unknown; the 1SD +/- goes from 0 and 105 m^2/ha, suggesting the data were not normally distributed; the top end for western gray squirrel are reported by Hall (1980) who reported 38 m^2/ha for ponderosa pine; 85 m^2/ha in knobcone pine, Garrison et al. (2005) reported 39 m^2/ha for black oak/p pine; Dodd et al. (2003) reported high quality Abert's habitat was >35 m^2/ha.*
3) Average canopy closure between 35 and 73 % (mean of primary areas 54% +/- 1 SD), with greater clumping (clumps of 0.1-0.5 ha) and connecting stringers needed at the lower canopy closures. *Harrod (1999) reported pre-settlement tree clumps were typically 0.09 ha, and cited Morrow (1985) who found clumps of 0.1-0.3 ha depending on age of individual trees in old growth ponderosa pine in Oregon. Connections of trees in clumps and stringers means crowns are ≤ 1 m apart. Pre-settlement southwestern ponderosa pine forest has been described by several studies; groups ranged from 2- 40 trees and varied from 0.05 – 0.7 ac in size usually connected by scattered individual; openings frequent and varied greatly in size (Covington et al. 1994); Keith (2003) suggests trees clustered in small, even-aged groups of 0.1-0.5 ha, in uneven-aged forest for Abert's squirrel; mean canopy closure in their study stands ranged from 32-59%].*
4) Minimum mean dbh of 23 cm (9.05 inches). *Uneven-aged stands; this is the mean for core areas in Klickitat County, but data from California and data from Abert's squirrel suggest that this may be far from optimal. The mean dbh of trees >10 cm in nest plots near Stehkein was 39.6 cm (15.6 in) (Hamer et al. 2005).*
5) More than 20 tree/ha (8 trees/ac) >15 inches dbh *This is an estimate, based on data on Abert's squirrel; missing from our data is a value for the number of large trees needed, and how large the trees need to be; most western gray squirrel nest trees are >15 inches; Dodd et al. (2003) reported that high quality Abert's squirrel habitat in Arizona had > 8 trees per ac in the 18-24 inch class; or the 12-29" class in Patton (1985). Fitzgerald (2005) reported several locations in Oregon that averaged 30 –99 trees > 30.5 cm per hectare (12-40 trees > 12" per acre) in 1917.*
6) Greater than 50 or 60% ground cover in litter; less than 20% understory in shrubs. *Historically, a higher percentage of the ground cover may have been in pine grass or bunchgrasses.*
7) A few scattered older cavity trees >10 inch dbh (e.g. oaks, cottonwoods, etc.).

8) Presence of additional food species within the annual home range, such as big-leaf maple, vine maple, California hazelnut, Oregon ash, Indian plum, serviceberry, or aspen; species will differ with region.

Western Washington (Based on high use stands in Ryan and Carey (1995b)[g]

1) Mixed Douglas-fir and oak with average of 53% Doug-fir, 34% oak, 13% other species; preferably > 8 ha patch size and within 600 m of water.

2) 172-315 trees/ha (70-128 trees/ac)[h]

Mean +/- 1 SD in Ryan and Carey (1995b). This data is based on where squirrels were seen, so may be somewhat biased toward open conditions in which squirrels are more visible.

3) Basal area of 19-35 m^2/ha (average was 27 m^2/ha) (83-152, mean of 117.6 ft^2/ac).

This is the BA for high use areas, upper desirable end unknown; the top end for western gray squirrel are reported by Hall (1980) who reported 38 m^2/ha for ponderosa pine; 85 m^2/ha in knobcone pine, Garrison et al. (2005) reported 39 m^2/ha for black oak/p pine; Dodd et al. (2003) reported high quality Abert's habitat was >35 m^2/ha.

4) dbh of Douglas-fir 40-57 cm (mean was 48.5 cm)(15.7 –22.4", mean = 19.1 inches dbh).

5) 34-49% understory in shrubs.

6) a few scattered older oaks with cavities.

7) 6- 10 food species present (mean was 8.3).

These included: snowberry, hazelnut, Indian plum, Douglas-fir, Oregon white oak, salal, serviceberry, Rosa spp., blackberry, red huckleberry, Ribes spp., bigleaf maple, vine maple, Oregon ash, ponderosa pine, cascara, Pacific yew, grand fir, Pacific dogwood, black cottonwood, and apple.

[a]Desirable characteristics for western gray squirrel habitat based on the studies of Linders (2000), Gregory (2005), and Hamer et al. (2005); in the absence of data for western gray squirrels, we considered data for Abert's squirrel habitat in Arizona ponderosa pine. These characteristics do not necessarily represent optimal habitat.

Appendix C. Tree squirrel hunting seasons in Washington, 1922 – 1954[a]

Year	Counties[b]	Season description	Season dates[c]	Bag Limit
1922-1923	All counties	Gray squirrel, fox squirrel, black squirrels	Closed	-
1924	Klic, Yak, Oka, Che, Clar, Cow, Thu	Fur-bearing animals	1 Oct.-31 Mar.	No limit
	Pie	Fur-bearing animals	1 Oct.-1 Mar.	No limit
	GrH, Lew, Ska, Clar, Cow	Fur-bearing animals	1 Nov.-31 Mar.	No limit
1925	Yak, Che, Oka, Thu	Fur-bearing animals	1 Oct.-1 Apr.	No limit
	Klic,	Fur-bearing animals	1 Oct – 31 Mar	No limit
	Pie	Fur-bearing animals	1 Oct – 1 Mar	No limit
	Cla, Cow, Lew, GrH, Ska	Fur-bearing animals	1 Nov.-31 Mar	No limit
1926[d]	Klic, Kit, Yak, Che, Oka, Clar, GrH, Thu, Ska	Other game animals	15 Sep.-1 May	No limit
	Lew	Other game animals	1 Oct.-30 Apr	No limit
	Cow	Other game animals	1-31 Oct.	No limit
	Pie	Gray squirrels	1-12 Oct.	No limit
1927	Klic, Oka	Other game animals	15 Sep.-1 May	No limit
	Cow	Other game animals	15 Sep.-30 Dec.	No limit
	Pie	Gray squirrel or black squirrel	1-15 Oct.	5/day
	Che, Lew, GrH, Thu, Ska	Other game animals	Closed	-
	Yak	Gray squirrel	Closed	-
	Cla	Gray or black squirrel	Closed	-
1928	Oka	Gray squirrel, black squirrel	16 Sep.-30 Apr.	No limit
	Thu	Gray squirrel, black squirrel	1 Oct.-1 Dec.	No limit
	Cow	Gray squirrel, black squirrel	1 Oct – 30 Nov	No limit
	Klic	Gray squirrel, black squirrel	15 Sep.-15 Oct.	3/day;7/wk;30/sea
	Pie	Gray squirrel, black squirrel	1-15 Oct.	No limit
	Clal[e]	Gray squirrel, black squirrel	1 –21 Oct	No limit
	PdO[e]	Gary squirrel, black squirrel	15 Oct – 1 Apr	No limit
	Kit, Yak, Che, Clar, Lew, GrH, Ska	Other game animals	Closed	-
1929	Thu	Gray squirrel, black squirrel	1 Oct.-1 Dec.	No limit
	Pie	Gray squirrel, black squirrel	1-31 Oct.	No limit
	Klic	Gray squirrel, black squirrel	15 Sep.-15 Oct.	Season limit 20
	Clal, Jef[e]	Gray squirrel, black squirrel	1 –21 Oct	No limit
	Yak, Che, Oka, Clar, Cow, Lew, GrH, Ska	Other game animals	Closed	-
1930	Pie, Thu	Gray squirrel, black squirrel	1 Oct.-30 Nov.	No limit
	Klic, Kit, Yak, Che, Oka, Clar, Cow, Lew, GrH, Ska	Other game animals	Closed	-
	Clal, Jef[e]	Gray squirrel, black squirrel	1 –21 Oct	No limt
1931	Pie, Thu	Gray squirrel, black squirrel	1 Oct.-30 Nov.	No limit
	Klic	Gray squirrel, black squirrel	1-21 Oct.	3/day
	Clal[e]	Gray squirrel, black squirrel	1 - 21 Oct	No limit
	Jef[e]	Gray squirrel, black squirrel	1 – 21 Oct	3/day
	Che, Oka, Yak, Clar, Cow, GrH, Lew	Other game animals	Closed	-
1932	Pie, Thu	Gray squirrel, black squirrel	1 Oct.-30 Nov.	No limit
	Klic	Gray squirrel, black squirrel	1-31 Oct.	3/day; 15/season
	Clal[e]	Gray squirrel, black squirrel	1 – 21 Oct	5/day
	Jef[e]	Gray squirrel, black squirrel	1 – 21 Oct	3/day

Year	Counties[b]	Season description	Season dates[c]	Bag Limit
	Che, Oka, Yak, Clar, Cow, GrH, Lew, Ska	Other game animals	Closed	-
1933	Pie, Thu	Gray or black squirrel	1 Oct.-30 Nov.	5/day
	Clal, Jef[e]	Gray or black squirrel	1 – 21 Oct	5/day
	All other counties	Gray or black squirrel	Closed	-
1934	Pie, Thu, Clal, Jef[e]	Gray squirrel, black squirrel	1-31 Oct.	5/day[f]
1935-1937	Statewide	Gray squirrel, black squirrel	1-31 Oct.	5/day[f]
1938	All of western WA and Klic-west of White Salmon River	Gray squirrel, black squirrel	1-31 Oct.	5/day[f]
1939	All of western WA	Gray squirrel, black squirrel	1-31 Oct.	5/day[f]
1940	All of western WA except lawful year around in Clar	Gray squirrel, black squirrel	1-31 Oct.	5/day[f]
1941	Klic and all of western WA except lawful year around in Clar	Gray squirrel, black squirrel	1-31 Oct.	5/day[f]
1942	Klic, Pie, Thu, Clar, Cow, Lew, Ska	Gray squirrel, black squirrel	1-31 Oct.	5/day[f]
1943	Klic, Pie, Thu, Clar, Cow, Lew, Ska	Gray squirrel, black squirrel	10-31 Oct.	5/day[f]
1944-1948	Statewide	Gray and black squirrel	Closed	-
1949-1950	Pie, Thu	Gray and black squirrel	1-30 Sep.	5/day
1951	Statewide	Gray and black squirrel	Closed	-
1952-1954+	Statewide	Gray squirrel	Closed	-

[a]Compiled from Hunting and Trapping Season pamphlets, Washington Division of Game and Game Fish (1922-32) and Department of Game (1933-1955).

[b]Does not include all counties with Fur-bearer or "other game animal" seasons, but only counties in regions with western gray squirrel populations or were gray squirrel was specifically mentioned. Abbreviations: Che =Chelan, Clal = Clallam, Clar =Clark, Cow = Cowlitz, GrH = Grays Harbor, Jef = Jefferson, Kit = Kittitas, Klic = Klickitat, Lew = Lewis, Oka = Okanogan, Pie = Pierce, Ska = Skamania, Thu = Thurston, Yak = Yakima.

[c]Season may include first and/or last date listed.

[d]Western gray squirrels were included in definition of "other game animals" in 1926.

[e]There is no evidence that populations of western gray squirrels existed in Clallam, Jefferson or Pend Oreille counties.

[f]Straight or mixed bag ("gray or black squirrels") or in possession.

Appendix D. Western gray squirrel conservation in Washington: significant events and publications, 1951-2005.

Year	Activity or publication
1951	Western gray squirrel season was closed statewide.
1954	Removed from State Game Hunting Pamphlets and considered "protected".
1970	Western gray squirrels were reintroduced onto the Oak Creek Wildlife Area using 10 squirrels from Oregon.
1973	Included in the Washington Department of Game (WDFW) brochure "*Rare Mammals of Washington*" (Lauckhart 1970).
1975	Barnum reported on Washington status and distribution in Master's thesis (Barnum 1975).
1978	Western gray squirrel was listed as "rare, uncommon, or of concern" in "*Species of Special Interest in the State of Washington*" (Tivel 1978).
1980	Washington Department of Game placed the western gray squirrel on the first Nongame Program "Species of Concern" list.
1983	Washington Department of Game completed a preliminary status review and classified the western gray squirrel as uncommon to rare with restricted habitat availability
1984	Study conducted on the status of the reintroduced population of western gray squirrels on the Oak Creek Wildlife Area (Gaulke and Gaulke 1984).
1987	Rodrick (1986) conducted surveys at historical sites in the Puget Trough and Klickitat County and recommended immediate protection due to apparent decline.
1993	Status report completed; Washington Fish and Wildlife Commission listed the western gray squirrel as a state-threatened species.
1993	USFWS recognized the western gray squirrel as a "species of concern" in western Washington.
1994	WDFW began systematic surveys of historic western gray squirrel sites in Washington.
1995	Publication of: *Biology and management of the western gray squirrel and Oregon white oak woodlands: with emphasis on the Puget Trough* (Ryan and Carey 1995a); and *Distribution and habitat of the western gray squirrel (Sciurus griseus) on Fort Lewis, Washington* (Ryan, L.A. and A.B. Carey. 1995b).
1996	*Final environmental impact statement on forest practice rules for: northern spotted owl, marbled murrelet, western gray squirrel* published by WDNR (1996).
1998	WDFW began a two-phase study of western gray squirrel home range, habitat and population characteristics in Klickitat County.
1999	Parametrix, Inc. completed a preliminary study on the genetic relatedness of western gray squirrels in Oregon and Washington.
2000	Phase I of WDFW study of home range, habitat and population characteristics in Klickitat County was completed and results summarized (Linders 2000). WDFW began Phase II of study on population dynamics, habitat, and reproduction.
2000	Tahoma Audubon and Northwest Ecosystem Alliance filed a petition with the USFWS on 29 December to list the Washington distinct population segments of the western gray squirrel as threatened or endangered.
2000	Study on the genetic relatedness of western gray squirrels from Washington, Oregon and California initiated by the University of Washington's Burke Museum.
2001	Bayrakçi et al. (2001) reported the results of surveys on Fort Lewis indicating dramatic decline in *Current Status of the Western Gray Squirrel (Sciurus griseus) population in the Puget Trough, Washington.*
2002	USFWS published a 90-finding that emergency listing of the Puget Sound population was not warranted, but initiated a status review to determine if one or more distinct population segments exist in Washington that warrant listing (USFWS 2002).
2002	Management strategy for oak woodlands on Fort Lewis was completed (GBA Forestry, Inc. 2002).

Year	Activity or publication
2003	WDFW completed research on the genetic relatedness of western gray squirrels from Washington compared to Oregon and California, increasing the sample size and expanding the results of a parallel study by the University of Washington (Warheit 2003).
2003	USFWS status review of the western gray squirrel results published on 10 June, concluded that the Washington population did not meet the criteria for a distinct population segment and was not a listable entity (USFWS 2003).
2004	WDFW issued report on the evaluation of squirrel nesting activity on forest practice sites subsequent to logging in Klickitat County, Washington (Vander Haegen et al. 2004).
2004	USFWS published a 90-finding on a 2002 petition that there was not substantial information to warrant listing the Washington population, the species, or any subspecies of western grays squirrel (USFWS 2004).
2004	The Nature Conservancy completed a guidance document titled *Strategies for enhancing western gray squirrels on Fort Lewis* (Fimbel 2004a).
2005	WDFW issued progress report on the research project in Klickitat County, Washington (Vander Haegen et al. 2005).
2005	Gregory (2005) completed study on habitat, home range and nest selection of western gray squirrels in Okanogan County, Washington.

Appendix E. Summary of guidelines for forest practices in Washington.

Management guidelines
1) Protect all western gray squirrel nests and nest trees.
2) Within a 50 ft radius of each nest tree, maintain a "no cut" buffer.
3) Within the next 350 ft of each nest tree, retain at least 50% canopy coverage, or an average tree spacing of 15 ft for trees 10 inch dbh or larger.
4) Maintain arboreal "stringers" of trees to water and to foraging habitat.
5) Avoid logging, road building or other noisy activity within 400 ft of all nest trees from March 1 through August 31.
6) Avoid blasting within 0.25 mi of nest trees during this same period.

Appendix F. Washington Administrative Code 232-12-297. **Endangered, threatened, and sensitive wildlife species classification.**

PURPOSE

1.1 The purpose of this rule is to identify and classify native wildlife species that have need of protection and/or management to ensure their survival as free-ranging populations in Washington and to define the process by which listing, management, recovery, and delisting of a species can be achieved. These rules are established to ensure that consistent procedures and criteria are followed when classifying wildlife as endangered, or the protected wildlife subcategories threatened or sensitive.

DEFINITIONS

For purposes of this rule, the following definitions apply:

2.1 "Classify" and all derivatives means to list or delist wildlife species to or from endangered, or to or from the protected wildlife subcategories threatened or sensitive.

2.2 "List" and all derivatives means to change the classification status of a wildlife species to endangered, threatened, or sensitive.

2.3 "Delist" and its derivatives means to change the classification of endangered, threatened, or sensitive species to a classification other than endangered, threatened, or sensitive.

2.4 "Endangered" means any wildlife species native to the state of Washington that is seriously threatened with extinction throughout all or a significant portion of its range within the state.

2.5 "Threatened" means any wildlife species native to the state of Washington that is likely to become an endangered species within the foreseeable future throughout a significant portion of its range within the state without cooperative management or removal of threats.

2.6 "Sensitive" means any wildlife species native to the state of Washington that is vulnerable or declining and is likely to become endangered or threatened in a significant portion of its range within the state without cooperative management or removal of threats.

2.7 "Species" means any group of animals classified as a species or subspecies as commonly accepted by the scientific community.

2.8 "Native" means any wildlife species naturally occurring in Washington for purposes of breeding, resting, or foraging, excluding introduced species not found historically in this state.

2.9 "Significant portion of its range" means that portion of a species' range likely to be essential to the long-term survival of the population in Washington.

LISTING CRITERIA

3.1 The commission shall list a wildlife species as endangered, threatened, or sensitive solely on the basis of the biological status of the species being considered, based on the preponderance of scientific data available, except as noted in section 3.4.

3.2 If a species is listed as endangered or threatened under the federal Endangered Species Act, the agency will recommend to the commission that it be listed as endangered or threatened as specified in section 9.1. If listed, the agency will proceed with development of a recovery plan pursuant to section 11.1.

3.3 Species may be listed as endangered, threatened, or sensitive only when populations are in danger of failing, declining, or are vulnerable, due to factors including but not restricted to limited numbers, disease, predation, exploitation, or habitat loss or change, pursuant to section 7.1.

3.4 Where a species of the class Insecta, based on substantial evidence, is determined to present an unreasonable risk to public health, the commission may make the determination that the species need not be listed as endangered, threatened, or sensitive.

DELISTING CRITERIA

4.1 The commission shall delist a wildlife species from endangered, threatened, or sensitive solely on the basis of the biological status of the species being considered, based on the preponderance of scientific data available.

4.2 A species may be delisted from endangered, threatened, or sensitive only when populations are no longer in danger of failing, declining, are no longer vulnerable, pursuant to section 3.3, or meet recovery plan goals, and when it no longer meets the definitions in sections 2.4, 2.5, or 2.6.

INITIATION OF LISTING PROCESS

5.1 Any one of the following events may initiate the listing process.

- 5.1.1 The agency determines that a species population may be in danger of failing, declining, or vulnerable, pursuant to section 3.3.
- 5.1.2 A petition is received at the agency from an interested person. The petition should be addressed to the director. It should set forth specific evidence and scientific data which shows that the species may be failing, declining, or vulnerable, pursuant to section 3.3. Within 60 days, the agency shall either deny the petition, stating the reasons, or initiate the classification process.
- 5.1.3 An emergency, as defined by the Administrative Procedure Act, chapter 34.05 RCW. The listing of any species previously classified under emergency rule shall be governed by the provisions of this section.
- 5.1.4 The commission requests the agency review a species of concern.

5.2 Upon initiation of the listing process the agency shall publish a public notice in the Washington Register, and notify those parties who have expressed their interest to the department, announcing the initiation of the classification process and calling for scientific information relevant to the species status report under consideration pursuant to section 7.1.

INITIATION OF DELISTING PROCESS

6.1 Any one of the following events may initiate the delisting process:

- 6.1.1 The agency determines that a species population may no longer be in danger of failing, declining, or vulnerable, pursuant to section 3.3.

6.1.2 The agency receives a petition from an interested person. The petition should be addressed to the director. It should set forth specific evidence and scientific data which shows that the species may no longer be failing, declining, or vulnerable, pursuant to section 3.3. Within 60 days, the agency shall either deny the petition, stating the reasons, or initiate the delisting process.

6.1.3 The commission requests the agency review a species of concern.

6.2 Upon initiation of the delisting process the agency shall publish a public notice in the Washington Register, and notify those parties who have expressed their interest to the department, announcing the initiation of the delisting process and calling for scientific information relevant to the species status report under consideration pursuant to section 7.1.

SPECIES STATUS REVIEW AND AGENCY RECOMMENDATIONS

7.1 Except in an emergency under 5.1.3 above, prior to making a classification recommendation to the commission, the agency shall prepare a preliminary species status report. The report will include a review of information relevant to the species' status in Washington and address factors affecting its status, including those given under section 3.3. The status report shall be reviewed by the public and scientific community. The status report will include, but not be limited to an analysis of:

7.1.1 Historic, current, and future species population trends.

7.1.2 Natural history, including ecological relationships (e.g. food habits, home range, habitat selection patterns).

7.1.3 Historic and current habitat trends.

7.1.4 Population demographics (e.g. survival and mortality rates, reproductive success) and their relationship to long term sustainability.

7.1.5 Historic and current species management activities.

7.2 Except in an emergency under 5.1.3 above, the agency shall prepare recommendations for species classification, based upon scientific data contained in the status report. Documents shall be prepared to determine the environmental consequences of adopting the recommendations pursuant to requirements of the State Environmental Policy Act (SEPA).

7.3 For the purpose of delisting, the status report will include a review of recovery plan goals.

PUBLIC REVIEW

8.1 Except in an emergency under 5.1.3 above, prior to making a recommendation to the commission, the agency shall provide an opportunity for interested parties to submit new scientific data relevant to the status report, classification recommendation, and any SEPA findings.

8.1.1 The agency shall allow at least 90 days for public comment.

FINAL RECOMMENDATIONS AND COMMISSION ACTION

9.1 After the close of the public comment period, the agency shall complete a final status report and classification recommendation. SEPA documents will be prepared, as necessary, for the final agency recommendation for classification. The classification recommendation will be presented to the commission for action. The final species status report, agency classification recommendation, and SEPA documents will be made available to the public at least 30 days prior to the commission meeting.

9.2 Notice of the proposed commission action will be published at least 30 days prior to the commission meeting.

PERIODIC SPECIES STATUS REVIEW

10.1 The agency shall conduct a review of each endangered, threatened, or sensitive wildlife species at least every five years after the date of its listing. This review shall include an update of the species status report to determine whether the status of the species warrants its current listing status or deserves reclassification.

10.1.1 The agency shall notify any parties who have expressed their interest to the department of the periodic status review. This notice shall occur at least one year prior to end of the five year period required by section 10.1.

10.2 The status of all delisted species shall be reviewed at least once, five years following the date of delisting.

10.3 The department shall evaluate the necessity of changing the classification of the species being reviewed. The agency shall report its findings to the commission at a commission meeting. The agency shall notify the public of its findings at least 30 days prior to presenting the findings to the commission.

10.3.1 If the agency determines that new information suggests that classification of a species should be changed from its present state, the agency shall initiate classification procedures provided for in these rules starting with section 5.1.

10.3.2 If the agency determines that conditions have not changed significantly and that the classification of the species should remain unchanged, the agency shall recommend to the commission that the species being reviewed shall retain its present classification status.

10.4 Nothing in these rules shall be construed to automatically delist a species without formal commission action.

RECOVERY AND MANAGEMENT OF LISTED SPECIES

11.1 The agency shall write a recovery plan for species listed as endangered or threatened. The agency will write a management plan for species listed as sensitive. Recovery and management plans shall address the listing criteria described in sections 3.1 and 3.3, and shall include, but are not limited to:

11.1.1 Target population objectives.

11.1.2 Criteria for reclassification.

11.1.3 An implementation plan for reaching population objectives which will promote cooperative management and be sensitive to landowner needs and property rights. The plan will specify resources needed from and impacts to the department, other agencies (including federal, state, and local), tribes, landowners, and other interest groups. The plan shall consider various approaches to meeting recovery objectives including, but not limited to regulation, mitigation, acquisition, incentive, and compensation mechanisms.

11.1.4 Public education needs.

11.1.5 A species monitoring plan, which requires periodic review to allow the incorporation of new information into the status report.

11.2 Preparation of recovery and management plans will be initiated by the agency within one year after the date of listing.

11.2.1 Recovery and management plans for species listed prior to 1990 or during the five years following the adoption of these rules shall be completed within 5 years after the date of listing or adoption of these rules, whichever comes later. Development of recovery plans for endangered species will receive higher priority than threatened or sensitive species.

11.2.2 Recovery and management plans for species listed after five years following the adoption of these rules shall be completed within three years after the date of listing.

11.2.3 The agency will publish a notice in the Washington Register and notify any parties who have expressed interest to the department interested parties of the initiation of recovery plan development.

11.2.4 If the deadlines defined in sections 11.2.1 and 11.2.2 are not met the department shall notify the public and report the reasons for missing the deadline and the strategy for completing the plan at a commission meeting. The intent of this section is to recognize current department personnel resources are limiting and that development of recovery plans for some of the species may require significant involvement by interests outside of the department, and therefore take longer to complete.

11.3 The agency shall provide an opportunity for interested public to comment on the recovery plan and any SEPA documents.

<u>CLASSIFICATION PROCEDURES REVIEW</u>

12.1 The agency and an ad hoc public group with members representing a broad spectrum of interests, shall meet as needed to accomplish the following:

12.1.1 Monitor the progress of the development of recovery and management plans and status reviews, highlight problems, and make recommendations to the department and other interested parties to improve the effectiveness of these processes.

12.1.2 Review these classification procedures six years after the adoption of these rules and report its findings to the commission.

<u>AUTHORITY</u>

13.1 The commission has the authority to classify wildlife as endangered under RCW 77.12.020. Species classified as endangered are listed under WAC <u>232-12-014</u>, as amended.

13.2 Threatened and sensitive species shall be classified as subcategories of protected wildlife. The commission has the authority to classify wildlife as protected under RCW 77.12.020. Species

Appendix G. Responses to written public comments received on the Draft Recovery Plan.

Note: page numbers refer to the draft western gray squirrel recovery plan, unless otherwise noted.

Section	Comment and response
Executive Summary	The Executive Summary states that habitat is being degraded by over-grazing. However, over-grazing of livestock was discontinued between the 1800's and early 1900's. Habitat in Klickitat County is not being degraded by over-grazing. *We changed the tense of the sentence, because the effect of historical grazing on forest structure is more important than any on-going impacts. Serious over-grazing in Klickitat County likely continued into the 1930s, as livestock numbers peaked around 1930 with 70,000 sheep, 15,000 cattle, and 7,000 horses (in 2002 there were 23,000 cattle, but <3,000 sheep)(Oliver et al. 1994, USDA-NASS 200). As stated, we do not know if livestock are having a significant direct impact on squirrels. However, grazing, like fire exclusion, probably continues to affect forest structure.*
Taxonomy	It's stated that the western gray squirrel in Washington are represented by three subspecies. Best Available Science that Parametrix Inc. provided proved that the three populations of western gray squirrel are not genetically different. *The 3 subspecies mentioned refers to the species entire range, not Washington alone; the other 2 subspecies are in California. Western gray squirrels are represented in Washington by 1 subspecies (*Sciurus griseus griseus*). The Parametrix data applies to the genetics of populations within Washington.*
Geographic Distribution	Were areas other than those described systematically surveyed in recent decades, or at any time? How confident is WDFW that the full distribution of the species is known? There are numerous areas of the state with mast-producing vegetation that might support squirrels. Unsurveyed areas in partially surveyed counties may also contain populations. The potential for more widely distributed populations should be discussed in greater detail. *The only systematic surveys prior to the 1990s efforts were Barnum (1975) and Rodrick (1986). We describe all the more recent efforts. Figures 9, 10, 11 indicate survey results. The rarity of records outside the main population areas, despite the daily observations of hundreds of knowledgeable biologists, foresters, and hunters is also important. Figure 2 and the accompanying text describe the full extent of habitats that might contain western gray squirrels. Additional squirrels likely exist in unsurveyed areas of Klickitat and Okanogan counties, but we do not expect that there are significant populations outside of the 3 main populations. We believe we have covered this concern thoroughly.*
	Washington is at the edge of the western gray squirrel's range, where populations will fluctuate. The Puget Trough and Okanogan are at the extreme edge. This should be discussed in the document. *We added a mention of this. Though the species range reaches its northern limit in Washington, it penetrates 200 miles into Washington, so the species should not be considered peripheral.*
	We feel that the species is not native to the Okanogan area and has been introduced. Providing a recovery plan and further regulation on a species that has been introduced doesn't make much sense.

Section	Comment and response
	A museum specimen collected at Manson in 1918 confirms that the western gray squirrel was found north of Lake Chelan. There is no evidence that they were introduced. They may have expanded their range further up the Okanogan River in response to the planting of walnut trees. However, western gray squirrel populations exist in Okanogan County that do not rely on walnuts (Gregory 2005). We discuss this in the sections on distribution and the Population Status, Washington: Past. The recovery plan addresses the statewide distribution of the species.
	The areas of Toats Coulee, and Mount Hull are far removed from potential western gray squirrel habitat and are highly unlikely to ever support western gray squirrels. We believe these areas were identified to put further regulations and restrictions in Okanogan County. *The outlying records are reliable. They may represent dispersing individuals, but without additional information, we can't dismiss the possibility of additional local populations. We present all the information we have. WDFW has no authority to protect western gray squirrel habitat; some counties may protect habitat of listed species.*
	The Plan has no scientific facts; it has been based on rumor, page 5. *The comment refers to the discussion of the rumors that western gray squirrels were introduced into the Okanogan or Puget Trough. The plan dispels these myths with reference to early museum records and published papers by scientific observers from the early 20th century.*
Natural History	Washington western gray squirrels seem to be particularly susceptible to disease. Translocation of more disease-resistant squirrels from south of the Columbia River might improve the genetic line. *This may be true, though squirrel populations in Oregon and California have also been known to crash due to disease and sometimes take a long period to recover. We may be using Oregon squirrels for translocations in the future.*
	Throughout the document, errors around estimates are reported as the standard error of the mean (SE). This parameter is a measure of the error of the estimate of the mean and does not provide information regarding the dispersion of the data. Dispersion of the data provides better insight into the range of habitats occupied by animals than does the mean and its standard error. Generally, 67 percent of a normal population will be found within one standard deviation of the mean and 95 percent of normal population will be found within two standard deviations of the mean. *We added standard deviations to the tables, and included 3 figures showing standard deviations. Standard error (SE) provides better information about the confidence in the mean, and is often reported because it is more useful when testing for differences between means. However, standard deviations (SD) does provide a better idea of the distribution of the raw data.*
	Automobile mortality maybe a good indicator that there is a viable population in Okanogan County.

Section	Comment and response
	Automobile mortality seems to be a function of road location and density, and has little to do with population size. Road kills are still occurring in the Puget Trough even though the population is near extinction; juvenile squirrels are particularly susceptible.
	Recent upswings of cougars in Klickitat County are probably impacting squirrel populations. *We don't have any data on cougar populations in Klickitat County. There are no reports of cougar preying on western gray squirrels; they are likely too small to be a regular item in their diet.*
	The old farmers around Klickitat County note that more California ground squirrels means fewer western gray squirrels. They also note when there are more badgers, there are fewer ground squirrels and more western gray squirrels. *It is unknown whether there is a direct relationship between western gray squirrel and California ground squirrel population trends. The observation of reverse relationship in the numbers of the squirrel species may be due to habitat changes; logging or other habitat changse may shift conditions to be more favorable for ground squirrels. California ground squirrels will spread to new areas when slash piles, rock piles, or road banks provide burrow locations. Badgers do eat a lot of ground squirrels. It would be interesting to do a removal experiment, removing the ground squirrels from an area and monitoring the western gray squirrels for a response in habitat use or population numbers. However, a well-done controlled experiment would be expensive, and may not be a high priority, in part because we'll never completely eliminate ground squirrels.*
	It is our experience that the greatest danger next to man shooting at a squirrel is cats. People let their cats roam the neighborhood and cats climb trees and kill the squirrels. Cats must be controlled. Perhaps we need a law making cat owners keep control of their pets like dog owners are forced to do. Cats should not be allowed to roam free. *We agree that cats kill young squirrels and lots of other wildlife. Cats and dogs may be two of the reasons western gray squirrels leave areas that become suburbanized. Many jurisdictions already have a leash law that applies to cats, but they are rarely enforced, and cat owners do not realize the impact cats have on wildlife through predation and the spreading of diseases.*
	Through the first 30 pages, very few studies are cited, but the authors cite their own research and observations in detail. These instances are frequent and given more weight than other scientific information, creating a bias. *We reviewed and recounted all the important information we could find on the species. The recovery plan emphasizes data and observations from Washington, where appropriate. The number of in-depth studies of western gray squirrels anywhere is limited. We summarize the important findings of all of them.*
	Habitat may be poor in Washington. Western gray squirrels are at the edge of their range, and squirrel density is naturally higher in Oregon and California. Few squirrels in Washington may not mean that they are "threatened," but may mean that Washington naturally cannot support very many.

Section	Comment and response
	There are fewer mast producing species in Washington, so densities of western gray squirrels are lower in Washington than in southern Oregon and parts of California. However, historical accounts of abundance suggest that squirrel numbers were considerably higher, and could be again if habitat conditions were improved. Since their range has contracted (in the Puget Trough and eastern Cascades) and their habitat has been degraded by roads, development, and logging, they are threatened by these factors.
Population Dynamics	This section needs a discussion of the effect of introduced species on population size. *There have been no studies or written reports on the effect of introduced species on western gray squirrel population size. One can assume that if introduced species compete with western gray squirrels for a limited resource, that one or both species would exhibit lower populations, and the added stress might exacerbate incidence of disease, etc.*
	Page 14, 2nd paragraph, 2nd sentence: The sentence should include an indication of the likely source(s) (e.g., eastern gray squirrels) of the large changes in population size in Pierce County – otherwise the sentence and the discussion of population dynamics, which does not address introduced species, leads the reader to assume that the large change in population size is within the range of natural variability. *Bowles (1921) attributed the large increase of the western gray squirrel in Pierce County to protection from hunting. They declined dramatically between the 1920s and 1950s. Scheffer (1952) attributed this decline to hunting and trapping; there were also dramatic changes in the south Puget Sound landscape during this period. Eastern gray squirrels were probably not a factor during that time period.*
	Table 3 contains probability values from paired tests using the Mann-Whitney-U Test. Mann-Whitney is appropriate for ordinal data (such as grades received by 2 sets of students), but not for continuous data, which we have here. *Not according to Sokal and Rohlf (1995); they provide an example using chigger measurements (p. 427-430). The test is a non-parametric test that uses the ranks, and not the actual measurements. See also in Zar (1996) p. 147-150.*
	Page 17 (home range overlaps): The numbers reported in the text do not appear consistent with the home range maps in Linders (2000). The overlaps are important because they are used for the population estimate. *In order to be able to compare their results to other studies, Linders (2000) and Gregory (2005) calculated mean overlap using software that takes pair-wise overlap for all the study animals; this results in factoring in zeros for non-adjacent individuals. This underestimates the actual percent of a home range that overlaps with any other squirrel, which may tend to lower the population estimate; we revised the statewide estimate because of this bias.*
Habitat Requirements	Page 20, Stand Characteristics, 3rd paragraph: The 1st sentence of the 3rd paragraph says squirrels favored conifer-dominated stands over mixed oak and conifer. The 4th sentence indicates that squirrels prefer stands with conifer overstory and oak understory. These sentences contradict each other.

Section	Comment and response
	The 4th sentence mentions that the stands most often used had a multi-layered canopy of pine and a sparse understory of oak. These would still be conifer dominated.
	The sample sizes in the 2 home range and habitat studies severely limit the applicability of the results, especially considering the inherent variability of tree squirrel habitat use. *The sample size for home ranges in Klickitat County is reasonable (52), but data from additional sites in the Okanogan would be helpful. Combining nest and core plots includes 302 plots for the Klickitat study area (Linders 2000); the Okanogan study sampled around 50 nest trees and 50 unselected control trees. Data from other sites in Washington would be useful, but such intensive studies are expensive and there are few areas with adequate numbers of squirrels. A study of the squirrel population at Stehekin on Lake Chelan may get underway in 2007 with funding from the National Park Service.*
	It is stated that large diameter trees are required, but in surveying our forests we found that there were as many nests (including good quality nests) in small diameter trees as in large diameter for pines. There seemed to be no preference for “dense forest” as opposed to open pine/scrub-oak areas with only 20-30% canopy cover. They do prefer trees that produce nuts though, or areas with nut producers. *There are no statements in the recovery plan that they “require,” or will only nest in large diameter trees. Studies in Washington found that most nests were in relatively large trees; in the Klickitat study the mean was 16.5”dbh, and they ranged from 6 - 30.6”. In the Okanogan study, the mean for all tree species was 17.7”, with a range from 8.7 - 33”. It is difficult to say if the squirrels on your land select habitat differently relative to canopy closure than those on the Klickitat Wildlife Area without sampling and statistical analysis. The habitat selection for moderate and dense stands reported by Linders (2000) was based on the core areas and radio telemetry; the number of nests or platforms that are only occasionally used might give a misleading impression of sparse habitat importance on your lands. The amount of pine seed and acorns would be related to the number of trees of significant size, and fungi sporocarp production is related to canopy closure.*
	Page 22, Table 6: The range of conditions within one standard deviation of the mean canopy closure for primary areas in Klickitat County extends from 35 to 73%, suggesting a preference for canopy closures in this range. The range and distribution of canopy cover is quite broad. Additional information regarding the range and distribution of canopy cover in the study area and/or the range and distribution of canopy closure in unoccupied habitat is needed to determine if these results reflect actual habitat preference or if the results merely reflect the range and distribution of available habitat. *In the Klickitat County study, the habitat type and canopy cover category were mapped for all squirrel locations plus a 300 m buffer. Then the location of home ranges and core areas and telemetry locations were plotted to determine if squirrels were selecting for canopy closure or type (oak, conifer, or mixed oak-conifer). At the home range scale, they selected for moderate density conifer and against sparse (canopy closure: $\leq$25% or dense$\geq$76%); at the core area scale there was some selection for dense conifer. In the Okanogan, characteristics at unselected trees were used as control sites and were compared to nest trees in the Okanogan study. Canopy closure in plots around 50 non-nest trees within home ranges averaged 30% and it was 45% at nest plots.*

Section	Comment and response
	Page 22, 2nd paragraph, last sentence: Gregory had an interesting finding. This sentence only captures ½ of the picture. In addition to a higher basal area, the selected sites tended to have only 50 trees per hectare while the control sites had an average of 387 trees per hectare. The paragraph alludes to a correspondence with larger trees, but the combination of basal area and tree density suggests a preference for sparse open stands with large trees, again, similar to the stands that are thought to have been present prior to fire exclusion. *50 was the nest tree sample size, not the trees per hectare; the correct stem density for Gregory's nest stands was 432 trees/ha (Table 5). However, the point about lower stem density with large trees in historical stands is a good one. We revised this paragraph and have added discussion of historic stand structure relative to western gray squirrel habitat needs in this section of the plan.*
	Page 23, paragraph 1, 1st sentence. The sentence states that squirrels frequently nest in conifer trees that are >40 cm dbh. But the data from Okanogan County indicate that the probability of nesting in a tree >40 cm dbh is equal to the probability of nesting in a tree <23.0 cm dbh. The majority of the nests (2/3 of the nests) were found in trees that ranged from 17.4 to 45.6 cm in diameter. This sentence should be rewritten to reflect the mean and range found by Gregory (2005). *The minimum nest tree diameter in Okanogan County was 22 cm, and from the standard deviation, 2/3 were between 32.3 and 57.7 cm (range 22- 84 cm). From the raw data, 66% (33/50) of nest trees were >40 cm (S. Gregory, pers. comm.). In Klickitat County, 2/3 of nest trees were between 29.3 and 54.7 cm (range 16-78 cm) and most of the nest trees in all 3 species (pine, oak, fir) were >40 cm.; the Klickitat mean was slightly smaller than the Okanogan, (42 vs. 45 cm), but the difference was not significant. In both areas, the nest trees had higher dbh than the surrounding plots, and in the Okanogan than non-nest control trees. Squirrels in these studies are selecting for large trees, but are limited by what is available.*
	Gregory researched and studied the western gray squirrel with little concern or coordination with local officials or staff. Her research and study would have been more appreciated if she had coordinated and informed local regulators and county staff. *Gregory studied a population on public land. It is not typical for a graduate student or researcher to coordinate and inform county officials before initiating research, however, this could be considered in future studies.*
	Gregory (2005) reported that nests were an average of 582 m (range 20-1,230 m) from perennial water, and it did not seem to be an important variable. This contradicts the drainages this species inhabits in the lower corner of Okanogan County. *The squirrel occupies canyons and drainages because that is where the suitable habitat is; data analysis provided no evidence that the proximity of water was an important factor in the selection of nest sites by squirrels in the available habitat.*
	On page 47, it is stated that "Large oaks and pines are the best mast-producers, and interconnected, conifer dominated stands of large diameter mast-producing trees are essential characteristics of good western gray squirrel habitat." It should be noted that these same interconnected forests are overgrown and very prone to drought, beetle

Section	Comment and response
	infestation and fire, and since the trees are struggling so much when their crowns are interconnected, they are not good mast producers. Trees that are touching are also very slow growers…which is bad for squirrel food. Note page 24 where it says open stands produce 3 times more cones per tree than dense stands. *The term interconnected might give a wrong impression, so we revised the language here and elsewhere. Both Linders (2000) and Gregory (2005) defined a connection as trees <1 m apart, as that is the distance that squirrels routinely jump. Optimal habitat has trees that are close enough to 1 or more other trees that squirrels can travel tree-to-tree. Gregory (2005) found less connectivity for nest trees in the Okanogan; 3 had none, and 3 had only one tree within a meter. That indicates that her study site was suitable, but not necessarily optimal. There is likely a balance between maintaining suitable conditions for squirrels and keeping trees healthy. Many stands are overly dense; historically, there would have been many fewer smaller trees and shrubs that use water and stress the trees. Isolated trees produce more cones per tree, but it is not known what density of trees will produce the most cones on a per acre basis. According to Harrod, et al. (1999) the stand structure was such that presettlement forest on average were low-risk to bark beetle attack. The clumped tree distribution probably made the stands suitable for western gray squirrels, despite the fairly low tree density.*
	We conducted a harvest of 150 acres in 2000, thinning to 15 ft spacing (thinning factor of 1.5), and leaving nest trees with interconnecting trees touching them. After 6 years, we have lost about 10% of trees that were left to beetles and the trees remaining are almost touching again. Areas that were set aside, or could not be thinned much due to squirrels were hit very hard by beetles, in fact at least 5% of marked squirrel nest trees have since died and fallen over. If I were to do it again, I would recommend a thinning factor of 1.8 or 1.9 (spacing of 18 or 19 feet for 10” trees), since that is what you will get anyway after another 6 years, and maybe not so many squirrel trees will die. *We appreciate that western gray squirrel were taken into consideration in your harvest planning. Thinning prescriptions that best benefit squirrels will depend on the site, the species growing there and their size. Protecting nests, leaving some large trees, and maintaining canopy cover, should be conducive to maintaining western gray squirrels on the site, but we also recognize that forest health is a critical part of the equation and must be considered when managing a stand for the long term. Addressing potential beetle problems would depend on the beetle species, the composition of the stand, etc. Thinning that retains a clumping pattern as described by Harrod et al. (1999) might minimize beetle problems while providing adequate connectivity for squirrels.*
	Very little seems to be known about the natal cavity nests. It is difficult to ascertain key relationships between nests and squirrel populations. There are no recovery recommendations specific to natal nest management. *We have added data from 39 natal den trees that had not been analyzed when the Draft was completed. Although cavities seem to be highly sought-after by females for natal dens, western gray squirrels do not require them to reproduce. Recovery tasks are not intended as a list of management recommendations, but we added mention of this under task 4.2.1.*

Section	Comment and response
	On p. 45 you mention that many nests are located in riparian areas; this contradicts the statement on page 43 that forest and fish legislation provides little benefit to western gray squirrels. *We revised the language slightly, but the forest and fish rules are designed to protect stream-dwelling fish and amphibians. It provides for managed stream buffers that could result in retention of some squirrel nest trees, particularly those near fish-bearing streams. However, the rules do not address squirrels directly and say nothing about the larger landscape outside of riparian management zones.*
	Study sites were not randomly selected in Klickitat County, creating biases that affect the existing information about habitat preference, home range, etc. In the future, random selection of occupied and control sites is recommended, as well as stratification of vegetative characteristics. *Random selection is ideal whenever possible. Often study site selection can be driven by ownership and the need for obtaining adequate samples of squirrels, etc. Randomization was used to locate sampling plots within nest sites and core areas, but the sites sampled for the habitat analysis in Linders (2000) were identified by telemetry and nest location. Gregory compared nest sites to sites at random unselected trees. Randomization can't be done at every scale, as one could end up studying unsuitable habitat and generate irrelevant data.*
	Population estimates are difficult to obtain with the existing data due to its non-random nature and inherent biases. Study sites were not randomly selected in Klickitat County, but were areas believed to represent the best habitat, and data from forest practice reviews are biased toward larger, denser stands ready for thinning or harvest. We recommend a future investigation using randomly selected study sites stratified by habitat type to determine occupancy rates of various habitats. This would facilitate the development of a more robust population estimate. *Good recommendation, though there will likely always be some selection at some scale because some landowners may not want their lands included, etc. We generally agree with the recommendation and recognize the biases.*
	Statistical analysis of the existing data should not be treated as conclusive due to biases, but should be used to develop hypotheses for future testing with statistically rigorous study design. *The existing data varies in the level of potential bias. For example, Gregory (2005) used 50 random non-nest unused plots as control sites, though her study area was selected because of the very limited number of areas with western gray squirrel populations on public land in Okanogan County. We don't think any of the biases fatally flaw the results which are consistent with the results of studies in Oregon.*
	Page 47, the draft stated that canopy closure less than 50% may be unsuitable. In old growth pine forests that are referenced as ideal habitat, the tree spacing would be very low and associated canopy coverage would likely be near or below 50%. *True; many pre-settlement pine and oak stands were likely below 50% canopy closure, but they had a clumped spacing pattern (see Harrod et al. 1999), so squirrels would*

Section	Comment and response
	have been able to move among several trees without traveling on the ground, and when they did travel on the ground, there was probably less woody cover. Managed stands often have even spacing and stands much below 50% likely have low connectivity. Connectivity for arboreal travel is likely more important today because fire exclusion and grazing has produced a more woody understory and squirrels seem reluctant to travel on the ground where there is much cover by shrubs. Maintaining some crown connectivity may be more important than strict adherence to 50% canopy closure. What Prather et al. (2006) stated for tassel-eared squirrels, may also be true for western gray squirrels here, "values in the 40-50% range are probably indicative of the lower thresholds for connectivity in the landscape."
Population Status	**Page 27, last paragraph**: Is there some bias in the lack of incidental observations – are western gray squirrels assumed to be eastern gray squirrels in some areas by some biologists based solely on location? *Perhaps, but biologists move and travel and some who are very familiar with western gray squirrels get around. Western gray squirrels are also very susceptible to road mortality. The near total absence of incidental records in areas outside the 3 population centers is telling.*
	Why do you cite unpublished data or reports, it lacks credibility? *In preparing status reports, we use all available information. This usually includes internal reports from surveys that we list as 'unpublished,' and data collected by researchers or graduate students that have not been included in their theses or publications. If we had any reason to doubt the reliability of the data we would not use it.*
	We object to using nests the same as counting squirrels. *Western gray squirrels are generally very secretive and the use of nests provide information about distribution and relative abundance that cannot otherwise be obtained without using intensive and expensive methods.*
	There has been very little actual survey hours conducted in Okanogan County relative to the other locations. It stated over and over that there is insufficient data. A recovery plan is premature. *We do need more data from Okanogan County and we plan to conduct additional surveys in 2007. The results of surveys and research may require future revisions of the recovery plan, but the plan is not premature.*
Habitat Status	The effects of European settlement have not been linked to the degradation or decline of the WSG. There is insufficient data to support or acknowledge the effects. *We provided ample discussion of the impact Euro-American settlement has had on habitat, particularly historic over-grazing, fire exclusion, logging of pines and oak, roads, and the proliferation of pets and eastern gray squirrels. However, settlement was an uncontrolled experiment.*

Section	Comment and response
	"Wildfires have destroyed large tracts of habitat in the Okanogan and likely contributed to the loss of western gray squirrel colonies in the Okanogan". This is speculation. The natural ecological regime included fire as one of the more important elements. *The historical fire regime in western gray squirrel habitat, including that in the Okanogan, was one of frequent low-intensity ground fires that maintained open stand structure. Fire exclusion has built up fuels and stand density such that wildfires are now high intensity stand-replacement events. The fires to which we refer were this kind of stand replacement event that eliminated all the trees.*
Conservation Status	The U.S. Fish and Wildlife Service determined that the petition to list the western gray squirrel under the Endangeed Species Act had not merit. *The western gray squirrel has been listed as a threatened species by the State of Washington since 1993. The U. S. Fish and Wildlife Service (USFWS) found sufficient merit in a 2000 petition to undertake a full 12-month status review. The 10 June 2003 findings by the USFWS relate to federal listing under the Endangered Species Act. The USFWS decision was that available information did not demonstrate the Washington populations have marked genetic, ecological, or behavioral differences compared to the remainder of the subspecies, and therefore did not constitute a distinct population segment and was not a listable entity under the ESA. They also found that the Washington populations were not significant to the rest of the taxon or constitute a significant portion of the range of the subspecies. The findings do not relate to the status of Washington populations relative to extinction, and the findings have no bearing on the relative merit of the species' state status of threatened.*
Management Activities	We appreciate that in the Introduction it is recognized that the success of recovery will depend on cooperative efforts. We recommend adding a discussion of interagency and public/private cooperation. *These are discussed in sections on surveys, logging, and adequacy of regulatory mechanisms; we added a brief mention of these in the introduction to this section.*
	The most valuable information, seems to have been disregarded. Parametrix (1999) concluded that there was little evidence for genetic divergence between the populations. It would seem appropriate that if WDFW felt that the sample size of squirrels was insufficient that continued data collection would have been reasonable. *In fact, we did gather DNA samples from >10 times the number of squirrels represented in the Parametrix study (Warheit 2003), as reported in the text.*
Adequacy of Existing Regulatory Mechanisms	WDFW should review the Columbia River Gorge National Scenic Area regulatory regime as it influences the health of western gray squirrel populations. *We added a brief discussion of this under federal regulations.*
	The best available science points to flaws in the forest practice guidelines and the need for better compliance. The available information suggests that there are measures that can be taken that will have a high likelihood of benefiting squirrels. Despite this information, the summary of strategies and tasks defers a decision as to the necessity of a

Section	Comment and response
	critical habitat rule to an uncertain date. The process for adopting a critical habitat rule should begin. While the Recovery Plan's emphasis on collaborating efforts with various stakeholders should be a high priority, regulatory action must also occur to beneficially complement collaborations. *We agree that an effective critical habitat rule is needed, and though the logic of the impact of logging is compelling, existing hard data is not. It is not clear that the existing guidelines would make an effective rule, and an ineffective rule may be worse than none at all. The guidelines may be revised in coming months, and we will revisit the issue of a rule at that time.*
	This Plan could negatively affect county land use planning. *Recovery plans are guiding documents and are not regulatory. Some counties address the needs of listed species through the planning and permitting processes.*
Factors Affecting	On page 1 it states that the population decline was probably the result of habitat degradation and historical over-hunting combined with sporadic outbreaks of disease, particularly mange. The invasion of the California ground squirrel in Klickitat County coincided with the introduction of mange into the western gray squirrel population and the subsequent 1930s die-off of the gray squirrel population. *Mange wasn't necessarily new to Washington, but a severe outbreak happened during a period when California ground squirrels were increasing. Mange epidemics were reported several times in California, including 1913, 1921, and 1970s, and we assume that western gray squirrel populations have long fluctuated with periodic outbreaks; some populations rebounded quickly and others did not recover for many years. In Washington, mange was reported in the 1930s, 40s, and 1950s (Gaulke and Gaulke1984, Stream 1993), so it does not appear to have been a single event. Mange may also have had a temporary, but severe, impact on the California ground squirrel population in 1950 (Clanton and Johnson 1954), though it is unknown what organism was responsible. The idea that California ground squirrels brought mange into Washington is an interesting hypothesis, but the only supporting evidence is that outbreaks occurred roughly in the same time period that California ground squirrels were expanding their range into Washington. The mite that causes mange in western gray squirrels,* Notoedres centrifera*, is considered specific to tree squirrels, and has never been reported in ground squirrels.*
	The guidelines for forest practices include maintaining a 50 ft no-cut buffer around nest trees. The 50 foot no-cut buffer will tend to result in an area that develops dense understory brush and a high density of saplings in the area of the nests. The data indicates a strong preference for open understories with little to no vegetation (Linders 2000). Hence, the 50-foot no-cut buffer will tend to create unsuitable habitat over time. No-cut areas in ponderosa pine forests eventually become overstocked, with tree densities reaching or exceeding 1000 trees per hectare. The data suggests that squirrels prefer habitat with roughly 250 to 700 trees per hectare. Hence, the stand density within the no-cut area will also tend to grow into habitat that is not suitable for squirrels. As the trees become overly dense, the stands are subject to infestation by insects and disease and are also at risk of catastrophic fire. The no-cut guideline should

Section	Comment and response
	be reconsidered. Management options that retain the preferred habitat characteristics over time should be explored. *The 50 ft no-cut buffer guideline is intended to protect the nest tree from damage and maintain the canopy connections. The same site would not necessarily contain a nest during subsequent harvest in the future, so the potential for increasing stand density may not be an important issue. One or more landowners has violated the guideline in order to remove saplings within the buffer, and this likely improved squirrel habitat.*
	The guidelines for forest practices include maintaining at least 50 percent canopy closure within 350 feet of nest trees. The 50 percent canopy closure left following a harvest will tend to increase over time. This will result in canopy closures near nests that range from 50 percent on up. The data indicates that squirrels primarily use areas with canopy closures in the range of 35 to 73 percent (with use tailing off in both directions from this range). Hence, the squirrels would be benefited if habitat were maintained within the range that they apparently prefer. A more logical management scenario would be to reduce canopy closure to 35 percent (while retaining sufficient large trees) and allow it to grow through 75 percent and then re-treat the site to reduce the canopy. *It is difficult to develop guidelines that consider the natural variability and complexity of natural systems while remaining sufficiently simple to implement. The guidelines will be reviewed to incorporate recent information (Task 4.2.2). One problem with a 50% canopy closure requirement is that in some pine stands this does not allow for any harvest. In these drier sites, a lower canopy closure is reasonable, if variable density thinning, or other methods, are used to clump trees to provide patches with canopy connections for arboreal travel and underground fungi production. Retaining trees in clumps and a component of large trees would more closely mimic historical stand structure. However, stands with evenly spaced trees and canopy closure of 35% is probably unsuitable to western gray squirrels.*
	Subsequent to the 1930s die-off of western gray squirrel, California ground squirrels occupied the high quality western gray squirrel habitat and still do today [personal affidavits signed by long time Klickitat County residents were attached to the comments]. *Whether western gray squirrels would occupy the dry, open oak/pine savannah to which you refer if California ground squirrels were not present is uncertain. All the habitat studies conducted, both where California ground squirrels are present (Klickitat, Oregon), and where they are not (Okanogan), indicate that western gray squirrels select moderate density, conifer or conifer dominated mixed stands. All studies note the importance of interconnected canopy that provides for arboreal travel. Western gray squirrel diet studies note the importance of fungi, the abundance of which is correlated with canopy closure (Lehmkuhl et al. 2004), and pine seeds that are a more reliable year-to year food source than acorns. Western gray squirrel go out of their way to feed on acorns when they are available, and females may locate maternal dens in oak cavities on open slopes hundreds of meters from core areas (Linders et al. 2004). The Western gray squirrel population prior to the1930s mange outbreak may have been extraordinarily high, contributing both to the observations in savannah, and to the severity of the population crash. Squirrels are more visible in open oak stands, so anecdotal observations by long-time residents that squirrels used to be found only in oaks are biased by this greater visibility, and therefore not sufficiently reliable to be the basis of*

Section	Comment and response
	recovery strategies. It would seem prudent to use the data we have on what squirrels are selecting, rather than anecdotal reports based on memories about what squirrels used to use.
	On page 19, it states that the habitat quality in Washington is thought to be relatively poor compared to the other parts of the species range due to the lower number of large-seeded, mast-bearing tree species. The statement "it is thought to be" is unacceptable without supporting data, or follow-up discussion as to the reasons for this condition. *We added some discussion in the text to address this. Western gray squirrel populations in Washington have only one species of pine and one species of oak, and the Okanogan squirrels do not have the oaks. Populations in California and southern Oregon have the advantage of more oak and pine species available. The large sizes of home ranges in Washington is evidence that the habitat in Washington supports fewer squirrels than that in the core of their range.*
	The interaction with the California ground squirrel is not only obvious, but is perhaps one of the most important aspects of western gray squirrel recovery. All recent observational studies of squirrel habitat use are post-invasion by California ground squirrel; contrast it with the pre-settlement forest conditions in which western gray squirrels formerly thrived. Historic stand conditions can be reconstructed from stumps, etc. These are the stand conditions present when squirrels were thriving. In Klickitat County some pre-settlement oak/pine savannas remain. These stands are on the steep canyon side wall of the gorge and other side canyons, including the west side of the Klickitat River down stream from the town of Klickitat, the north side of the Columbia River Gorge from the Klickitat River to the White Salmon River, the White Salmon from its mouth to the Wingartner Bridge, Major Cr Canyon and the Rattlesnake Cr Canyon. A total of about 14,000 ac of this oak/pine savannah remains. This habitat is currently occupied by the gray digger, and very few if any western gray squirrels. Has the gray digger displaced the western gray squirrel into a substandard habitat? Shouldn't we focus on habitat preferred by western gray squirrels? Habitat preferences today may not be the same as they were prior to the invasion of the California ground squirrel and other introduced species. *Pre-settlement pine forests may have had lower average canopy closure than squirrels are using today, but presettlement stands were clumped, providing some canopy connectivity, and periodic fires reduced woody vegetation in the understory. With little understory vegetation, squirrels are more inclined to travel on the ground; a lower canopy closure may have been tolerable for the squirrel before fire exclusion and overgrazing increased pine regeneration and woody understory.* *The Klickitat River Canyon includes the heart of one of the largest western gray squirrel populations (e.g. Klickitat Wildlife Area), so the statement that it has high numbers of ground squirrels and low western gray squirrel is not a good generalization. Some of the pine/oak savannah habitat you describe has too much shrubby understory, and some is too sparsely timbered, and may never have been preferred habitat of western gray squirrels; the data on western gray squirrels habitat selection in Washington is very comparable to habitat used in Oregon and California, and the canopy closure of selected habitat is similar in the Okanogan where California ground squirrels are not found.*

Section	Comment and response
	California ground squirrels inhabit more open areas and will invade western gray squirrel habitat where logging and disturbance remove the overstory and provide slash or rock piles and road banks for burrow sites. If the California ground squirrel has had any effect on habitat use by western gray squirrels, the ability to remedy that is probably very limited. It isn't clear how the California ground squirrel became established in Washington, but it is clear that it is here to stay. Eradication of the California ground squirrel is not a realistic option. Experiments in which California ground squirrels are removed while population and habitat use of western gray squirrels are carefully monitored would be very interesting. If competition proved to be important, recovery strategies might include limited ground squirrel control in certain areas, and managing habitat in ways that does not increase ground squirrels.
	This recovery document relies heavily on the hypothesis that the loss and degradation of habitat is the primary reason that the western gray squirrel is a threatened species in Washington. In the Klickitat area, habitat changes throughout the past 4-5 decades have been slow, and in many cases habitat is similar to pre-settlement conditions, especially along the Klickitat River Canyon and south slopes above the Columbia. Still, squirrel populations are low. Suggestions of habitat-based rules and plans in this type of situation can be very risky, especially when most of the land is privately held. If owning squirrel habitat has financial consequences, there is a good chance that habitat will be lost. *Although mange, road-kill mortalities, and possibly competition with other species are significant problems, it is most likely that western gray squirrels can overcome these factors where the habitat is in good condition. Habitat condition also affects whether an area is suitable for California ground squirrels and the severity of mange epidemics. Habitat is being lost by clearcutting and conversions, and degraded by roads. Habitat change has been slow, but nonetheless substantial.*
	Long-time residents tell about the sudden die-off of the western gray squirrel in the 1930s when the habitat was still in prime condition, and that they were never able to make any substantive recovery. Many attribute the mange die-off to the invasion by the California ground squirrel. The plan does not describe this event, but the 1998-99 outbreak is described in detail and given more emphasis. I am wondering how many outbreaks have occurred during the last 7 decades. To describe the 98-99 outbreak as an event seems like a stretch. *We added emphasis in the plan to the reported severity of the 1930s outbreak in Klickitat County. Local residents give various dates for the mange outbreak, from the late 1920s, 1931-32, 1932-33, 1935-36. It may have been a period of drought or other stress that caused a severe, and prolonged mange outbreak. Western gray squirrels continued to be legally hunted in Klickitat County during this period until 1944, with the exceptions of 1930 and 1933; the reason(s) for the lack of recovery to the abundance described in the 1920s is unclear. Also, it isn't clear that the habitat was in prime condition in Klickitat County in 1930 since that was the peak in total livestock numbers in the county (70,000 sheep, 18,000 cattle, and 7,000 horses; Oliver et al. 1994). Mange outbreaks tend to coincide with food shortage, and the timing of the 1930s outbreak coincides with the worst drought in the 20th Century that likely affected mast, fungi, and pine seeds. Western gray squirrel may have appeared to never recover because they were seen less often; habitat near homes and farms may have been degraded by firewood cutting, clearing for pastures, and become more suitable for California ground squirrels. In*

Section	Comment and response
	contrast to this perception, western gray squirrels did rebound after mange epidemics on the Klickitat Wildlife Area, where habitat is in relatively good condition. There have undoubtedly been periodic outbreaks in the last 70 years, as this seems to be characteristic of western gray squirrels, as well as other tree squirrel populations. The 1998-99 outbreak is described in detail because it occurred during a research project, and we were therefore able to document the mite species responsible, and the high percentage of mortalities of the study population.
	Nutritional stress appears to be a contributing factor to the incidence of mange in Klickitat County. Pine seed production is positively correlated with tree diameter. Based on this information, forest practices influence the impact of mange and other diseases on western gray squirrel populations. *Agreed. Some thinning harvests can increase pine seed production if productive trees are left, but reducing canopy closure can also negatively affect hypogeous fungi production.*
	It appears that mange severely limits western gray squirrel populations. Developing a trap and treat program may prove critical to their conservation, especially for smaller populations. *We agree that the potential for this should be investigated, including pilot projects. However, mange treatments require 2 applications 10 days apart, essentially requiring expensive and stressful captivity. If a single application treatment was available that could be administered to prevent infection, then it may be feasible to treat a portion of specific core populations, (e.g Klickitat Wildlife Area) during an epidemic. However, this strategy might be counter-productive if it circumvented natural selection for disease resistance.*
	There is no discussion at all in regards to the possibility that climate change may have placed the continuation of western gray squirrel this far north in jeopardy. *Since the climate is warming, Washington may become more suitable for oaks and pines, thus improving conditions for western gray squirrels, and the species range may begin retreating from its southern end and advancing northward. However, the instability created by rather rapid change may be problematic and creates great uncertainty about its effects on species.*
	On p.47, 80 years seems too long to produce a 15 inch pine. *True, it isn't typical, but up to 80 growth rings were counted on stumps or in cores using an increment borer at dry sites in Klickitat County (M. Linders, pers. obs.).*
	Every effort should be made to control the population of exotic competitors to give the western grays squirrel an opportunity to increase. *A limited experiment in control of eastern gray squirrels was initiated in 2006 in Pierce County. If results are encouraging, additional removal projects may be planned for eastern gray squirrels and fox squirrels. Whether the California ground squirrel is an important competitor is not known; habitat and diet overlap seems to be limited and they spend a large portion of the year in hibernation. However, this is a topic in need of research, which is identified in the plan.*

Section	Comment and response
	Hunting should be allowed and all other legal protection dropped on the non-native eastern gray squirrels, which is an abundant and widespread pest. It is an agricultural pest, competes with native species and causes a large fraction of electrical power outages. *The eastern gray and fox squirrels can be hunted year-round with any type of hunting license and there is no bag limit. Unfortunately, the favored habitat of eastern gray squirrels is suburban yards and parks where shooting is prohibited; these areas act as sources of dispersers to western gray squirrel habitat. The potential for shooting mortality of western gray squirrels due to mistaken identity is an additional risk of encouraging hunting of the introduced squirrels.*
	In Klickitat County, the deer population is very high, certainly much higher than in pre-Columbian times. The season should be open to any deer in Klickitat County, not just 3-point bucks. Deer compete directly with squirrels for acorns and eat vast quantities every year. Deer kill or damage regenerating pines and oaks. The deer population needs to be drastically reduced if squirrels are to have a long-term hope. *We don't know what the deer population was in pre-Columbian times, and the habitat has changed substantially, so carrying capacity has likely changed. Game surveys and harvest suggest that the deer population in Klickitat County has been declining, and we have restricted harvest. The more common complaint is that there are too few deer in Klickitat County. We have no data suggesting that deer are altering vegetation communities. Deer do eat acorns and young trees. Deer would only compete with squirrels for acorns in fall and winter when the acorns have fallen to the ground, and deer don't eat pine nuts or underground fungi, so we don't think that competition with deer is a major problem.*
	Several paragraphs are given to the eastern gray squirrel but only one short paragraph is given to the wild turkey. The wild turkey eats nearly all the same foods as the western gray squirrel and uses the same habitats. In addition, the turkey normally travels in groups. If you have ever followed a group of turkeys feeding, it is plainly obvious they are having an effect on available food. The burden of proof should be on the turkey, and in favor of a native threatened species. I advocate reducing potential competition, until or unless, research indicates that competition is not a threat. I suggest including squirrel areas (especially in the Okanogan where we have no oaks, in a more liberal turkey hunting framework; specifically this would be an 'any turkey' early fall season and late fall permits. *The discussion of turkeys under Ecological Relationships was brief because very little is known about the relationship between squirrels and turkeys. We expanded the discussion specific to turkeys in Washington under Factors Affecting and identify the need for research on this topic (task 6.2.3). If competition is found to be affecting western gray squirrels populations, WDFW will change turkey management to reduce numbers in areas occupied by western gray squirrels (Task 2.2.4). The introduced eastern gray and fox squirrels have a much higher potential to impact western gray squirrels than turkeys. There is also more information about eastern gray squirrels because eastern grays are also an introduced pest in Europe that is impacting the native red squirrel. Competition with turkeys would only occur seasonally, as turkeys do not forage in trees as do squirrels.*

Section	Comment and response
	Turkey numbers in Klickitat County have skyrocketed over the past few years. *Based on harvest and hunter effort figures, they have increased somewhat, but not dramatically. Turkey numbers increased from 2001-2002, but seem to have remained stable since then. In 2005, 345 turkeys were taken in Klickitat and Skamania counties by about 1,500 hunters (see turkey harvest data at: http://wdfw.wa.gov/wlm/game/harvest/2005/turkey_general.htm.)*
	Cows do very little damage to oak roots. I can show you living oaks in cattle feed pens and winter "sacrifice" fields that get severely trampled, but the oaks are doing fine. Cows do not usually graze oak trees, they are a food of last resort. Deer, however, do get hungry in the winter and do eat oaks. We suggest you make it clear that the degree of effect is closely related to the intensity of the grazing. Livestock on Klickitat County open ranges tend to be rather dispersed. *You are correct. Larsen and Morgan (1998) mention that cattle will not usually eat oaks until forage is depleted; consumption of oaks (primarily sprouts) occurs after intense grazing or in late summer when grasses dry up. We revised this section.*
	On page 51, it states that Klickitat County is open range. Only parts are open range, many parts are not. Most cattle in Klickitat County are managed in fenced pastures and guided by a grazing plan. It states grazing may be a localized problem in squirrel habitat. Our land is grazed heavier than most open range is grazed, and we have not observed any localized problems for squirrels, except perhaps around water troughs and ponds. But squirrels use these to drink water that would not be available if there were no cows. *We revised this section.*
	We are very disappointed that WDFW would base its recovery plan on incomplete information. It is unacceptable to base a recovery plan on assumptions that livestock grazing "Often eliminates many native forbs and may inhibit growth of mycorrhizal fungi" *There is no such thing as complete information. These assumptions are not important ones for the recovery plan, but are well founded. Zimmerman and Neuenschwander (1984) noted very distinct changes in forb species occurrences between grazed and ungrazed plots. Rummel (1951) reported that several forb and shrub species which are good forage species were present on the ungrazed Meek's Table, but absent from Devil's Table in Yakima County; the herbaceous understory was also 1.8-2.5 times higher on Meek's Table. Bethlenfalvay and Dakessian (1984) reported lower mycorrhizal colonization of grasses in rangelands degraded by grazing.*
	Without scientific "peer-reviewed" research there is no way to know if domestic livestock are causing damage to western gray squirrel habitat; the lack of science in this key area is unacceptable and should be a large enough issue to require the draft to be re-written. *You are correct that it is not possible to know whether that is occurring under today's stocking levels without research. However, this does not appear to be a major issue for western gray squirrels, and should not delay recovery planning and actions. Historic*

Section	Comment and response
	over-grazing by livestock had a dramatic impact on ponderosa pine forests (see discussion below); livestock could affect squirrels by alteration of herbaceous understory and suppressing fungi through soil compaction.
	The WDFW needs to do a better job of researching livestock grazing before making a broad-brush statement that "grazers eliminated fine fuels that historically carried ground fires" (page 51). This is an assumption that is not backed up by any facts! *The historical concordance between the introduction of large numbers of livestock and the cessation of the high frequency fire regime before effective fire suppression is well documented for several study areas (Madany and West 1983, Savage and Swetnam 1990, Agee 1993:334; and sources cited in Belsky and Blumenthal 1997).*
	Page 51, 1st paragraph: Belsky and Blumenthal (1997) and Rummell (1951) address situations where areas were heavily grazed and then grazing was <u>discontinued</u>. Early in the 20th century, large concentrations of animals were present on the landscape in many areas of Washington. This has not been the case since the 1930s or earlier. Where grazing continues, the density of animals has been reduced in keeping with current knowledge regarding range management. Where grazing is discontinued, the changes in vegetation, as was described by Belsky and Blumenthal (1997) and Rummell (1951), can be expected (fed also by fire exclusion). The experimental enclosures in Klickitat County verify the situation. This paragraph needs to be modified to make sure the reader understands that change in vegetation occurred when grazers were removed. The paragraph currently reads as if active grazing creates the over-dense understory conditions. There are few grazing management experts that would agree with that. Grazing managers are usually much more concerned about over-grazing that results in stripped understory vegetation and trampling of trees and tree roots. In order to maintain the sparse vegetation preferred by western gray squirrels, habitat will have to be grazed, periodically burned, or hand cleared. The overall timbre of the paragraph is one that suggests that grazing is bad for squirrels. Grazing may, however, be one of the best tools available for maintaining habitat quality. Suggest rewording the paragraph. *This is not correct. Rummell (1951) states that Devil's Table "has been heavily utilized by livestock during the past 40 years". In some of the studies reviewed by Belsky and Blumnethal (1997), grazing had been discontinued, but the huge increase in pine regeneration occurred during the period it was being grazed (Madany and West 1983, Zimmerman and Neuenschwander 1984). In the Madany and West (1983) study, tree recruitment on the grazed plateau increased 10X or more during the years of high livestock densities, while recruitment on the ungrazed mesas remained unchanged. Livestock generally do not eat conifers, and unless very heavily stocked they will not reduce the woody understory. The utility or impact of the current level of grazing where prescribed fire cannot be used to restore open pine forest conditions is not known. The immediate effect on western gray squirrels may be insignificant, except that it may affect the ability to use prescribed fires in restoration work due to the reduction of fine fuels.*
	The statement based on Belsky and Blumenthal and Larsen and Morgan that "the long term effects of livestock appears to be an increase in woody understory" and that grazing is not recommended "within riparian zones" are not based in science or on managed grazing systems. It is essential that WDFW biologists review science from the cattle industry that documents the many benefits of managed livestock grazing on both

Section	Comment and response
	forage production and habitat condition. It is essential that WDFW consider current management practices before issuing a final recovery plan. *The papers by Rummel (1951), Madany and West (1983), and others reviewed by Belsky and Blumenthal (1997), provide convincing evidence that historic livestock grazing resulted in dramatic increases in ponderosa pine and fir regeneration.* As *Zimmerman and Neuenschwander (1984) state for their study area, "Livestock grazing was probably the principal factor in creating and maintaining conditions that favored increased tree regeneration." The historical and ongoing negative impacts of livestock grazing on streams and riparian vegetation are numerous and well documented by experimental and comparative studies (as reviewed by Belsky et al. 1999). As for the potential benefit of improved grazing regimes on riparian areas, Belsky et al. (1999) state, "Although the possibility of streams recovering their plant cover and ecological functions while providing food and water for livestock use is appealing (i.e., a win-win situation), it is largely contradicted by existing evidence."* *All this said, current grazing activity is probably not a big issue for western gray squirrels, and the recovery plan is not a regulatory document and unlikely to have any effect on ranchers.*
	The WDFW needs to focus on their mismanagement of elk at the Oak Creek Feeding Station. The Oak Creek site is a prime example of overstocked wildlife that results in WDFW feeding hay through the winter. WDFW needs to address the riparian impacts of elk and other wildlife and not just focus on domestic livestock. *Large concentrations of ungulates, whether elk or livestock, can do considerable damage, particularly to riparian habitat. Elk feeding sites at the Oak Creek wildlife Area have been shifted out of riparian habitat over the years (except on Nile Creek which is not good squirrel habitat).*
	Why doesn't the plan mention current grazing practices such as, rotational grazing, rest rotation, flash grazing or intensive grazing systems? We question the studies that the plan cites. *Most of the discussion is about the impact of historical grazing on the structure of ponderosa pine forest. It is unknown whether modern practices eliminate any impact that livestock have on resources important to western gray squirrels, or minimize or reverse the shift to overstocked stands at risk to catastrophic fires. Except for a few secondary sources (e.g. Larsen and Morgan 1998, Dunn 1998), the studies cited in the grazing section were published in respected peer-reviewed journals, including Journal of Range Management, Ecology, Journal of Soil and Water Conservation, and Conservation Biology.*
	The current regulations and other hurdles for private ranchers already hinders their abilities to utilize lands for grazing and produce an income. Placing further regulations will continue to drive them out of business. *Western gray squirrel recovery is unlikely to have any effect on ranching, and the plan does not propose any regulations pertinent to livestock grazing.*

Section	Comment and response
	Throughout the recovery plan it is stated in several locations that grazing has affected the western gray squirrel population. Yet in contradiction, under Other Human-related or Natural Factors the first sentence is "The specific relationship between grazing and the western gray squirrel habitat requirements has not been studied". This is an attempt to single out a valuable economic agricultural resource by speculating the effects. This is not acceptable. What will happen to the 67 grazing leases currently held by WDFW in Okanogan County? *The recovery plan does not state that grazing has directly affected western gray squirrel populations. As stated, the impact of historic over-grazing on forest structure and the ponderosa pine fire regime is probably more important that any impact of current levels of livestock grazing. On WDFW lands, grazing leases are renewed as long as they are consistent with ecological integrity and with the desired ecological condition for those lands (WDFW Policy POL-C6003).*
	Livestock grazing, timber harvest, and recreation contribute substantial amounts of revenue to counties. WDFW should study the economic impact the plan will have on counties. *Recovery plans are not regulatory documents; thus they do not have impacts on counties.*
	We believe that private landowners should have the right to manage their property any way they see fit unless the Federal Government would like to compensate them for the limitations it would like to place on private property. *This recovery plan is not a regulatory document and has nothing to do with the federal government. It primarily outlines research and management needs and general strategies for WDFW staff and provides initial target population numbers that may be revised at a later date.*
	We would like WDFW to use a collaborative approach to recovery plan development. Collaboration would be in the best interest of the squirrel, WDFW, the counties, and their landowners. *Recovery plan development is primarily a technical undertaking. Technical staff are included in peer review and then there is a public review process. Implementation of recovery plans is a very collaborative undertaking, requiring the participation and cooperative efforts of agencies, landowners, tribes, and other stakeholders.*
	Threats to habitat used by western gray squirrel include development, roads, logging, wildfire and fire suppression. Further evidence rather than speculation should accompany such a statement. *The importance of these factors for western gray squirrel habitat are self-evident and logical. The impact of development and roads are most obvious in the Puget Sound area, but road mortality is also important in Okanogan and Klickitat counties. The history of fire-exclusion, logging and grazing dramatically changed ponderosa pine forests and oak woodlands making stand-replacement wildfires more likely. Stand-replacement type wildfires have eliminated some habitat near Lake Chelan and along the Tieton River in the last 10 years, and may continue to destroy large areas of habitat in coming years.*

Section	Comment and response
	The economic impacts on logging, grazing, development suggested by the plan could be critical to private property rights and Critical Area Ordinances. *The recovery plan is not a regulatory document. Any effect of county or state regulations have on economic activity relate to the fact that the species is listed, not the recovery plan. The western gray squirrel has been state-listed since 1993. WDFW is mandated to preserve, protect, and perpetuate the wildlife of the state of Washington. We do not believe that the recovery of the western gray squirrel is necessarily incompatible with logging, grazing, or economic development.*
	I am very concerned about the large-scale industrial wind power development that is currently taking place in Klickitat County. The county regulations do not provide adequate protection for this species, and do not specifically require squirrel surveys before permits are issued, and do not adequately consider cumulative impacts of multiple wind projects. *To date, the impact of wind power projects has not been a major concern for western gray squirrels. The recovery plan focuses on the more immediate effects of development, logging, and roads on habitat.*
	The draft mentions an expansion of the Black Canyon snowpark that eliminated nesting habitat; I have snowmobiled from that park for 30 years and to my knowledge only a new outhouse was installed in that area. *We deleted this information because we were unable to confirm it. Either the report cited exaggerated some minor brush clearing or there was confusion about the location.*
Recovery	With a myriad of threats and an estimated minimum population of only 379, the western gray squirrel should be up-listed to endangered. *We considered this, but decided that the Klickitat population appeared to be relatively stable and therefore, the species may not meet the definition of endangered.*
	Western gray squirrels will be considered recovered at a population of 4,600; however, the Puget Trough, and maybe the Okanogan may not be sustainably recoverable, and even Klickitat County may not be recoverable. Instead the recovery objective should be a higher number of squirrels throughout the state, including locations not currently known to have squirrels, but known to have good habitat. Then an objective of 7,000 to 10,000 would be reasonable. *We hope to recover western gray squirrels in all areas of their historical range in Washington that have substantial quantities of suitable habitat. Given what we understand about habitat requirements, we think good habitat is somewhat limited and we would be reluctant to set a recovery objective higher than what we have identified. Recovery plans are dynamic documents, and can be reviewed and revised in the future based on new information.*
	A robust trend indicator to gauge success of recovery efforts is needed *We agree, but development and testing of such a tool is a challenging research project;*

Section	Comment and response
	we have been using grid trapping to measure squirrel density on Klickitat WLA, but the development and testing of a less intensive method that could be applied more widely would be very useful.
	The Plan calls for the importation of 3,300 squirrels into Okanogan County; never in history has Okanogan County had this many squirrels. *This is incorrect. The Plan has an interim recovery objective for the North Cascades Recovery Area of >1,000 adults. Translocation of squirrels into Okanogan County will be considered if it is deemed necessary for genetic reasons or to re-establish populations that appear to have gone extinct.*
	Base de-listing goals on the amount of occupied habitat; this would be straightforward and provide tangible goals for all parties involved. *We considered doing this, but one would have to carefully define "occupied," so that sink habitat (where squirrels are present, but unable to reproduce) was not characterized as adequate. Ultimately, the desirable goal is self-sustaining populations, large enough to be 'viable' if that is possible, and the way to measure that is with population numbers, not acres.*
	The Puget Trough should be abandoned for squirrel recovery; the area cannot support a sustainable population, and the recovery objective may be unattainable. It means continued high expense for a marginal population at the expense of the other two areas that appear more recoverable. If not abandoned, then new colonies should be established in more rural areas where there is more room to succeed (such as the Coast range, Olympics, San Juans, or Cascade foothills). *It is not yet known what can be achieved in the south Puget Sound area, and funds expended on squirrel recovery in the area doesn't necessarily subtract from funds available for recovery elsewhere. Advantages here include good partners in the U. S. Army and The Nature Conservancy who have been shouldering much of the work on squirrel recovery in the Puget Trough, as well as public lands managed by the Army, WDFW, DNR, and Thurston County. An additional benefit of the work here is that lessons learned on translocation, monitoring methods, eastern gray squirrel removal, etc. can be applied elsewhere. Most of the areas you mention are outside the historical western gray squirrel range and in Western Cedar-Western Hemlock habitat types and not likely to be suitable. The San Juans have some oak woodland, but probably do not have sufficient public lands to support a population.*
	There is no reason to believe that putting more land in public or trust ownership will contribute to recovering the squirrel population. *An outstanding example of the advantages of public ownership for conservation is Fort Lewis. Fort Lewis likely supports more state threatened and endangered species (at least 8) than any other similar-sized area in the south Puget Sound. Where occupied habitat in good condition exists, and is at-risk of development or logging, easements or acquisition can preclude degradation and loss and facilitates future habitat improvement that will maintain the local population.*

Section	Comment and response
	If western gray squirrels are valuable, then pay landowners for documented squirrels on their land. Landowners could be paid to protect nests for a specified period of time, perhaps 5 years, at which a new survey would be required. If the landowner will make more money on trees than on squirrels he will have no incentive to protect squirrels. The system would result in very quickly reaching recovery goals, because landowners would find many squirrels that the state is not aware of. The system could be paid for by re-allocating the estimated $550,000+ budget in Table 11, or through new timber harvest fees, new voter approved taxes, or by environmental foundations. The system could be adjusted to offer premiums for certain locations. It would still be illegal to harm squirrels or nests and they would still be protected. But now landowners would be actively working for squirrels and collecting data. *This is an intriguing though rather radical idea for species conservation. One apparent misconception is that the estimated recovery budget in Table 11 is actually available and dedicated to squirrel recovery. The Table estimates what it would cost to implement recovery strategies. WDFW does not currently have all that money such that it could be re-allocated for an incentive plan. The current commitment of funds for species conservation is inadequate for a major shift toward financial incentive programs. However, such a system could be tried on an experimental basis if a source of adequate funding were available. This would be consistent with task 4.2.3, "Explore alternative ways and incentives…" Environmental certification is a market-based approach potentially available for larger timberland owners that can help recapture costs associated with protecting wildlife and fish habitat.*
	WDFW needs to take the lead in restoring habitat by controlling logging, excavation, and development in sensitive areas, similar to what the Columbia River Gorge Commission does in the scenic area. *This level of regulatory power would require additional authority to protect habitat that can only be granted by the state legislature. Other agencies, such as WDNR and counties have regulatory authority to protect habitat for listed species.*
	WDFW should contract with willing landowners to restore habitat; programs like the Landowner Incentive Program (LIP) work well. *Agreed, LIP is a good program, and we should continue to assist landowners with seeking grants. Additional funds are needed for restoration work on private land.*
	Task 2.2.3 Add California ground squirrel *As far as we know, California ground squirrels reached Washington on their own, and therefore are native, in contrast to the introduced eastern gray and fox squirrels. We would support a removal experiment to investigate potential competition, but since eradication is not feasible, we are unlikely to be doing control. Managing habitat so that it does not encourage California ground squirrels while improving conditions for western gray squirrels would be more effective in the long run.*

Section	Comment and response
	WDFW should investigate possible migratory corridors between the Klickitat population and western gray squirrel habitat in Skamania and Clark County. *This is a good idea; however, suitable habitat is limited to a narrow strip in the Columbia River Gorge and maintaining habitat values for western gray squirrel will be difficult given development pressures and eastern gray squirrel presence. Protecting and restoring habitat in core areas is currently the highest priority.*
	WDFW must continue to work in county land use planning process. *We agree.*
	WDFW should develop guidelines for residential development that minimize negative impacts to squirrel habitat. Some consideration of regulatory measures is required by WAC 232-12-297.11.1.3. This may include a prohibition on urban development in critical habitat and limitations on how low density development proceeds. *WDFW has no regulatory authority over residential development impacts on western gray squirrel habitat. Protection of squirrel habitat depends on the counties or municipalities using their authority to seek and apply recommendation for maintenance of western gray squirrel habitat. WAC 232-12-297 does not require regulatory measures, but identifies regulations as one approach among many to reach recovery objectives.*
	Task 5.1.1: Task implies that grazing and squirrel habitat are mutually exclusive. Add the use of livestock grazing as a management strategy to maintain ground cover within the range of western gray squirrels. Removal of grazing will tend to result in a dense understory. This should be modified to include studies to determine the interactions between various grazing management approaches and the resulting habitat condition. Grazing programs found to enhance and/or maintain habitat should be implemented. *Livestock grazing at current levels may do little direct harm to western gray squirrels, but is unlikely to help restore pre-settlement conditions. Historical grazing helped produce the current overstocked conditions, and there is little or no reason to think that livestock grazing will encourage native grass understory while preventing overstocking with regenerating pine, fir, and other woody vegetation.*
	Under Strategy 5 in the recovery section it states that non-native trees and shrubs should be discouraged, but on page 19 it indicates that high tree species diversity is a characteristic of good habitat. We should improve habitat with species found in good habitat in Oregon and California. *Diversity can be improved somewhat using native species without using non-native species. Although the idea of adding mast-bearing species is attractive, introducing new species to an area is risky, and often results in unintended consequences. The spread of Sudden Oak Death by nursery stock is an example of why the planting of non-native species is discouraged; exotic filbert worms that eat acorns is another example. Whether climate change in the future will require more drastic measures, such as changing the species composition of forest lands, remains to be seen.*

Section	Comment and response
	Several places in the draft, Douglas-fir is referred to as an undesirable species, but the rare Doug-fir on our property are more likely to have squirrel nests than are the oaks and pines. *Douglas-fir are used for nests (16% of 232 nests were fir; Linders 2000), and provide food, too. Douglas- fir invasion of oak woodland is a problem in the Puget Trough, and Douglas- fir and grand fir has invaded some areas that were historically ponderosa pine, producing over-stocked, stressed stands that are ripe for wildfire. Pines provide a better food source than Douglas-fir; too many Doug-fir shift the habitat in favor of the Douglas squirrel which is a conifer seed specialist.*
	There is no mention of research on wild turkeys or California ground squirrels. *We mentioned these in task 6.2.3.*
	Habitat restoration alone will not restore the western gray squirrel populations in Klickitat County. *Agreed; however, habitat protection and improvement are very important parts of the recovery strategy for western gray squirrels throughout the state.*
	Reintroductions should be done as much as possible. There are many areas in Washington that can support western gray squirrels that do not have them now. If healthy animals can be brought from Oregon or California, they would thrive and eventually improve the gene pool. *Translocations, where squirrels are moved into areas with existing squirrel populations are part of the recovery strategy. A translocation plan for the Puget Trough population is currently being developed. Possible source populations are the Okanogan and Oregon. After testing and refining methods during Puget Trough work, we will explore reintroductions into suitable unoccupied habitat in other areas.*
	Deregulate the importation and moving of squirrels. For native western gray squirrels, it should be easy for anyone to import and release them. Private parties could quickly repopulate many areas of the state if allowed. *Regulation of the importation and release of wildlife is an important activity for many reasons. Unregulated and illegal introductions are why we have the problems of non-native eastern gray and fox squirrels to worry about, and may be how California ground squirrels colonized Klickitat County. Past introductions of opossums, nutria, bullfrogs, snapping turtles, and red-eared sliders are more examples of problem species brought into the state that have created many problems. Disease is another example of the risk of unregulated species introductions. In addition to the risk of introducing diseases that affect native populations, there is the potential for polluting the gene pool with different subspecies, or individuals that are adapted to a different habitat. Other concerns include humane treatment of the animals, and complicating law enforcement. The WDFW does use volunteers on some projects. When WDFW is ready to do a reintroduction, we would consider the involvement of volunteers if it can be done efficiently.*

Section	Comment and response
	Task 5.4 (develop a landscape approach to habitat management)—given the diversity of land ownership and large number of parcels, this would be difficult to implement. *True, but it may be possible to develop plans that address larger ownerships and provide better protection for habitat values while providing more flexibility than nest-focused guidelines or rules.*
	The first paragraph on page 12 (acorn dispersal) is largely supposition, and doesn't seem relevant to the document. *We removed some of this paragraph.*
	Why don't you use volunteers to do surveys? *As described in the discussion of survey efforts, we used volunteers in Klickitat County in the 1990s surveys. Where there is potential confusion with eastern gray squirrels, volunteers need to be well trained. Volunteer efforts require significant staff time to organize. It may be possible to use volunteers again in the future to determine distribution or after a monitoring scheme is developed. 'Citizen science' is an important priority for the WDFW.*
	The knowledge necessary to restore the western gray squirrel is not available at this time. Only after exhaustive research can a true recovery strategy be put in place. *We agree that our knowledge is incomplete, that is why we list several topics of research and mention that, "Recovery objectives may be modified as more is learned about the habitat needs, disease, and population structure of western gray squirrels." Recovery plans are dynamic documents and are updated with new information.*
	The protection of habitat at known sites is a legitimate need but to propose protection and improvement of any additional habitat outside of research projects is unnecessary and overly burdensome to landowners. *Western gray squirrels need stands of pine and oak of adequate size to provide abundant mast, an interconnected canopy, and sufficient canopy closure to provide abundant fungi. If we only protect these habitat values in research areas, western gray squirrels will not persist. Some landowners have been willing and able to adjust their management to conduct timber harvests and maintain western gray squirrel populations on their property.*
	The real value of this recovery document is that it points out in glaring fashion how little is known about the plight of the western gray squirrel in Washington. *We agree that more research on several topics is needed and this is identified in the plan.*
	You need to take all extreme measures to save the western gray squirrel. Their survival overrides all other concerns including economic concerns. Extinction is forever. *Maintaining the species in Washington is the goal of the recovery plan.*

WASHINGTON STATE STATUS REPORTS AND RECOVERY PLANS

Status Reports

2007	Bald Eagle	√
2005	Mazama Pocket Gopher, Streaked Horned Lark, Taylor's Checkerspot	√
2005	Aleutian Canada Goose	√
2004	Killer Whale	√
2002	Peregrine Falcon	√
2001	Bald Eagle	√
2000	Common Loon	√
1999	Northern Leopard Frog	√
1999	Olympic Mudminnow	√
1999	Mardon Skipper	√
1999	Lynx Update	
1998	Fisher	√
1998	Margined Sculpin	√
1998	Pygmy Whitefish	√
1998	Sharp-tailed Grouse	√
1998	Sage-grouse	√
1997	Aleutian Canada Goose	√
1997	Gray Whale	√
1997	Olive Ridley Sea Turtle	√
1997	Oregon Spotted Frog	√
1993	Larch Mountain Salamander	
1993	Lynx	
1993	Marbled Murrelet	
1993	Oregon Silverspot Butterfly	
1993	Pygmy Rabbit	
1993	Steller Sea Lion	
1993	Western Gray Squirrel	
1993	Western Pond Turtle	

Recovery Plans

2007	Western Gray Squirrel	√
2006	Fisher	√
2004	Greater Sage-Grouse	√
2003	Pygmy Rabbit: Addendum	√
2002	Sandhill Crane	√
2004	Sea Otter	√
2001	Pygmy Rabbit: Addendum	√
2001	Lynx	√
1999	Western Pond Turtle	√
1996	Ferruginous Hawk	√
1995	Pygmy Rabbit	√
1995	Upland Sandpiper	
1995	Snowy Plover	

√: These reports are available in pdf format on the Department of Fish and Wildlife's web site: http://wdfw.wa.gov/wlm/diversty/soc/concern.htm.

To request a printed copy of reports, send an e-mail to wildthing@dfw.wa.gov or call 360-902-2515