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Periodic Status Review for the Western Gray Squirrel

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Washington Department of
FISH AND WILDLIFE
Wildlife Program

The Washington Department of Fish and Wildlife maintains a list of endangered, threatened, and sensitive species (Washington Administrative Codes 220-610-010 and 220-200-100). In 1990, the Washington Wildlife Commission adopted listing procedures developed by a group of citizens, interest groups, and state and federal agencies (Washington Administrative Code 220-610-110). The procedures include how species listings will be initiated, criteria for listing and delisting, a requirement for public review, the development of recovery or management plans, and the periodic review of listed species.

The Washington Department of Fish and Wildlife is directed to conduct reviews of each endangered, threatened, or sensitive wildlife species at least every five years after the date of its listing by the Washington Fish and Wildlife Commission. The periodic status reviews are designed to include an update of the species status report to determine whether the status of the species warrants its current listing status or deserves reclassification. The agency notifies the general public and specific parties who have expressed their interest to the Department of the periodic status review at least one year prior to the five-year period so that they may submit new scientific data to be included in the review. The agency notifies the public of its recommendation at least 30 days prior to presenting the findings to the Fish and Wildlife Commission. In addition, if the agency determines that new information suggests that the classification of a species should be changed from its present state, the agency prepares documents to determine the environmental consequences of adopting the recommendations pursuant to requirements of the State Environmental Policy Act.

This is the Periodic Status Review for the Western Gray Squirrel. It contains a review of information pertaining to the status of Western Gray Squirrels in Washington. It was available for a 90-day public comment period from February 10, 2023 through May 10, 2023. Comments received were considered during the preparation of this final periodic status review. The Department will present the results of this periodic status review to the Fish and Wildlife Commission at a meeting in September 2023.

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Cover photos by Joe Higbee (squirrel), and Linda Steider (habitat at Soda Springs)

This work was supported in part by personalized and endangered species license plates

Washington State Periodic Status Review for the Western Gray Squirrel

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EXECUTIVE SUMMARY

The Western Gray Squirrel is one of three native tree squirrel species in Washington. It was historically distributed at low elevations from Pierce County southward to Clark County, through the Columbia River gorge, and in low to mid-elevations along the eastern Cascade Mountains from Klickitat to Okanogan counties. Current distribution in the state is now primarily limited to three areas: the Klickitat region (Klickitat, southern Yakima, and southeastern Skamania counties); the North Cascades (Okanogan and Chelan counties); and the southern Puget Trough (Joint Base Lewis-McChord and small areas off-base in Pierce and Thurston counties).

Although not well documented, Western Gray Squirrels were probably once uncommon to locally common across much of their range in Washington. The species was in decline by the late 1800s and was considered rare by 1970. In 2007, the statewide population was estimated to be between 468 and 1,405 squirrels (937 ± 50%) based on data from 1994-2005. Populations have not been estimated since, but occupancy surveys were conducted 2018-2020 to establish a baseline for monitoring trends in coming years.

In the past decade, the southern Puget Trough population may have increased somewhat due mainly to habitat work and augmentation of the squirrel population on Joint Base Lewis-McChord (JBLM) in 2007-2012. Research and local surveys in the North Cascades since that time suggested the population was higher than the 2007 estimate, but likely declined following wildfires in 2014, 2015, and 2021. An assessment of change in availability of Western Gray Squirrel primary habitat between 1993 (listing) and 2017 found gains from successional processes (e.g., tree recruitment and tree growth) did not compensate for habitat loss. Estimated net loss of habitat totaled 20.8% for the North Cascades and 21.2% for the South Cascades (Vander Haegen and others 2022). Wildfire was the dominant disturbance in plots examined in the North Cascades while timber harvest predominated in the South Cascades.

Known threats important to Western Gray Squirrel populations in Washington are habitat loss, degradation, and fragmentation; small population size and isolation; disease; and road mortality. The factors most linked to habitat loss for Western Gray Squirrels include timber harvest, wildfire, land conversion, and fire exclusion. Climate change is both a current and potential future threat to habitat through increased size and/or frequency of stand-replacement fires, changes in resulting stand composition and ongoing effects on food supply such as production of fungi and seeds.

Although the southern Puget Trough population may have increased slightly since the recovery plan was completed in 2007, it is very limited in size and constrained by the area and fragmentation of its habitat. Because of the species' relatively small total population size throughout the State, isolation of the three populations, continuing threats of wildfires and timber harvest, and a likely decline in primary habitat of >20% in both the North Cascades and Klickitat regions it is recommended that the Western Gray Squirrel be uplisted to endangered in Washington.

INTRODUCTION

Washington supports a diverse native and non-native squirrel fauna comprised of 19 species of tree squirrels, ground squirrels, marmots, chipmunks, and flying squirrels. The Western Gray Squirrel (*Sciurus griseus*) is one of five tree squirrels found in the state, three of which are native. Western Gray Squirrels have been considered rare in Washington since at least 1970 (Lauckhart 1970) and became a state threatened species in 1993. The species is not federally listed; a petition to list the Washington population under the Endangered Species Act was denied (USFWS 2003).

This periodic status review summarizes the biology, population status, threats, and recent management activities for Western Gray Squirrels in Washington and assesses whether the species should retain its current protected status or if it deserves reclassification under state law. A more detailed review of the species' biology, past status, population stressors in the state, and required recovery actions appeared in Linders & Stinson (2007).

DESCRIPTION AND LEGAL STATUS

The Western Gray Squirrel, the largest native tree squirrel in Washington, has a dark gray pelage on the back and flanks contrasting with pure white on the belly and throat (Carraway & Verts 1994, Verts & Carraway 1998). It also features a long bushy tail that is gray with white-frosted outer edges, and prominent ears that can occasionally be reddish-brown on the back in winter and are the only part of the animal's pelage that may have any brown. The large size, long bushy tail, and dark gray pelage lacking any brown on the body or tail distinguish Western Gray Squirrels from other squirrels in Washington. Vocalizations include a hoarse "chuff-chuff-chuff" barking. Three subspecies are recognized, with *S. g. griseus* present in Washington.

Figure 1. Western Gray Squirrel (*photo by Joseph V. Higbee*).

The Western Gray Squirrel is classified as state threatened in Washington and as a "vulnerable sensitive species" in Oregon. They are not protected under the federal Endangered Species Act.

DISTRIBUTION

The species is distributed from north-central Washington southward through western Oregon, California, and the west-central edge of Nevada to northern Baja California in Mexico (Linzey and others 2008, Escobar-Flores and others 2011). In Washington, it was historically distributed in low elevations from Pierce County southward to Clark County, through the Columbia River gorge, and in low to mid-elevations along the

eastern Cascade Mountains from Klickitat to Okanogan counties (Figure 2; Linders & Stinson 2007). Current distribution in the state is now primarily limited to three geographically discrete areas: the Klickitat region (Klickitat, southern Yakima, and southeastern Skamania counties); the North Cascades (Okanogan and Chelan counties); and the southern Puget Trough (Joint Base Lewis-McChord [JBLM] and small areas off-base in Pierce and Thurston counties) (Figure 2; Linders & Stinson 2007). Small, scattered populations may also remain in parts of Clark, central and northern Yakima, and Kittitas counties. Elevational range in Washington extends primarily from near sea level to 1,300 m (4,265 ft), with a few additional records reaching 2,140 m (7,030 ft; WDFW Wildlife Survey Data Management [WSDM] database).

NATURAL HISTORY

Behavior. Western Gray Squirrels are generally arboreal and solitary, and are adept at traveling through the tree canopy, but will also forage and move about on the ground, usually near trees (Ingles 1947, Cross 1969, Foster 1992). Western Gray Squirrels avoid large forest openings, instead using arboreal routes for escape, cover, and access to nest trees. The species is mainly diurnal, with daily activity levels highest in the hours just after sunrise. Activity occurs year-round but is greatest in autumn when extensive feeding and caching of food takes place. Western Gray Squirrels are typically secretive and wary by nature, but individuals have partially habituated to human activity in some locations.

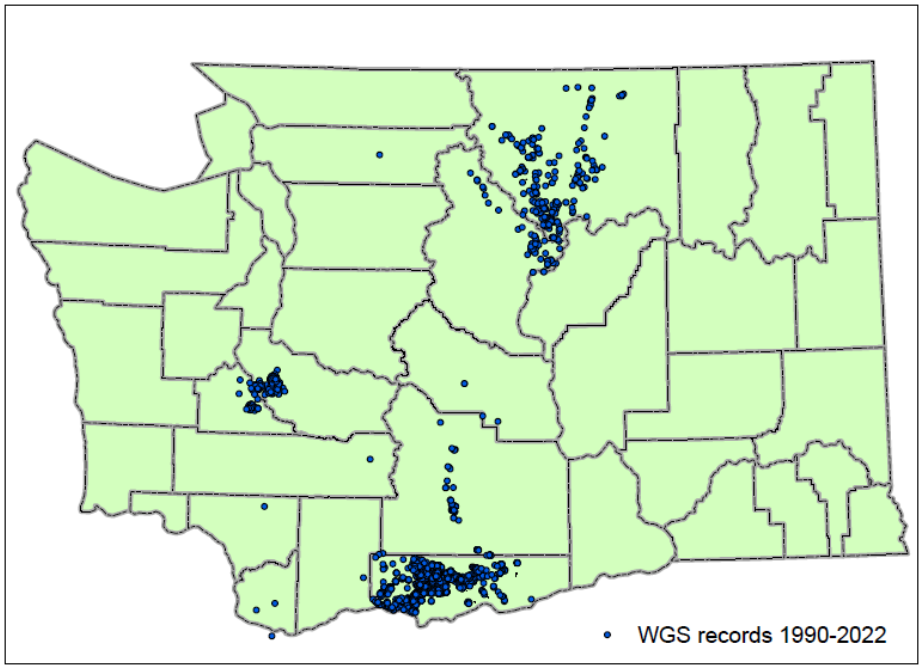

Figure 2. Western Gray Squirrel occurrences (squirrels and nests) in Washington from 1990-2022 (WDFW WSDM database).

The species uses two main types of nests (stick nests and tree cavities) for resting, sleeping, and rearing young. Stick nests (dreys) can be either large round covered shelters for winter use or rearing young, or broad platforms for seasonal or temporary use (Ingles 1947, Cross 1969, Linders 2000). Both are constructed with sticks, twigs, leaves and moss, and lined with grass, moss, lichens, and shredded bark. External

dimensions of stick nests are 17–36 in (43–91 cm) in diameter and up to 18 in (46 cm) in height (Grinnell & Storer 1924, Ingles 1947, Foster 1992). Stick nests are usually built adjacent to the trunk in the top third of the canopy (Foster 1992). When available, tree cavities are often selected by females for giving birth and rearing young. Individual squirrels occupy multiple nests over the course of a season, with an average of 14.3 nests used per animal in Klickitat County (Linders 2000) and 5.9 nests used per animal in Okanogan County (Gregory 2005). Breeding females sometimes use more than one nest when rearing a litter (Gregory 2005). Many nests are used by multiple squirrels throughout a season.

Habitat requirements. Forest stands occupied by Western Gray Squirrels must provide adequate nest sites, food, and escape cover. Favored stands consist of clumps of trees that form a dense upper canopy intermingled with areas of lower canopy cover and small canopy gaps (Linders & Stinson 2007, Linders and others 2010). Higher quality habitat commonly includes transitional, conifer-dominated areas that merge with open patches of oak and other deciduous trees. Mature, large-seeded mast-producing trees provide abundant food and sites for nest construction, with Ponderosa Pine (*Pinus ponderosa*) and Oregon White Oak (*Quercus garryana*) especially important in Washington (Linders 2000, Gregory 2005, Hamer and others 2005). Larger trees (i.e., >16 in [38 cm] diameter at breast height, hereafter dbh) typically offer greater food and cover. Additional features of higher quality habitat include an interconnected canopy for arboreal travel (Ryan & Carey 1995a, 1995b, Linders 2000, Gregory 2005) and relatively sparse ground cover. Squirrels may also visit isolated, open-grown trees to obtain seeds or when traveling across open expanses (Linders and others 2010). Habitat connectivity is essential for Western Gray Squirrels, facilitating movement between habitat patches, predator avoidance, access to mates, and juvenile dispersal (Linders and others 2010). Almost any treed habitat can provide connectivity, but movement corridors of mature trees and an irregular or complex canopy structure are more likely to be used. The linear nature of riparian areas makes them important travel corridors, especially in areas where dry uplands support limited tree cover.

Large trees, food, an open understory and canopy connections are the main habitat features, but some characteristics differ between the three regions. For example, Western Gray Squirrels in the Klickitat region favor conifer-dominated stands over mixed Oregon White Oak-conifer and pure oak stands (Linders 2000, Linders and others 2010). Nests in one study in Klickitat County were placed most frequently in Ponderosa Pine (72%), and less often in Douglas-fir (*Pseudotsuga menziesii*; 16%), and Oregon White Oak (12%; Linders 2000). Nest trees were typically >40 cm dbh and were larger with more interlocking crowns than surrounding stands (Linders 2000). In the southern Puget Trough, Western Gray Squirrels primarily inhabit upland areas dominated by conifers with little shrub cover (Johnston and others 2020). Squirrel use has also been reported to be higher in mixed conifer-Oregon White Oak stands with more Douglas-fir than oak (Ryan & Carey 1995a). Riparian areas and stands of pure oak are used substantially less. Large trees, particularly Douglas-fir are preferred for nesting, but oak, Ponderosa Pine, Oregon Ash (*Fraxinus latifolia*), Black Cottonwood (*Populus balsamifera*), and Bigleaf Maple (*Acer macrophyllum*) are also used (Johnston 2013). Oak is absent in the North Cascades, so squirrels occur mainly in mixed conifer-deciduous forests comprised of Douglas-fir and Ponderosa Pine with smaller amounts of Lodgepole Pine (*Pinus contorta*), Black Cottonwood, Bigleaf Maple, and Trembling Aspen (*Populus tremuloides*) (Stuart 2012). Within Western Gray Squirrel home ranges, core-use areas had greater canopy cover, a greater number of tree species, and trees with higher live crowns compared to low use areas (Stuart and others 2018). Nesting areas are

characterized by greater canopy cover, tree connectivity and Dwarf Mistletoe (*Arceuthobium* spp.) infection. Large Ponderosa Pine and Douglas-fir trees with crowns connecting to adjacent trees and containing mistletoe brooms are most often used for nesting (Hamer and others 2005, Gregory and others 2010, Stuart and others 2018).

Reproduction and breeding behavior. Western Gray Squirrels attain sexual maturity at 10–12 months of age (Fletcher 1963, Swift 1977). In Washington, most females are pregnant by February or March, with litters born from March to July. The last litters are usually weaned by late August (M. Linders & M. Vander Haegen, unpubl. data in Linders and others 2010). Litter sizes range from one to five young, with 3 being most common (Vander Haegen and others 2018). Typically, one litter is born annually (Linders 2000, Gregory 2005), although in rare instances females may rear a second litter (Vander Haegen and others 2018). Pregnancy and nursing last about 44 days and 56 days, respectively (Swift 1977).

Diet and foraging behavior. Primary foods of Western Gray Squirrels include hypogeous (below-ground) fungi (truffles and false truffles), pine nuts, acorns, Douglas Fir and other seeds, green vegetation, and fruit (Stienecker & Browning 1970, Stienecker 1977, Linders & Stinson 2007, Johnston and others 2019). In Washington, hypogeous fungi are widely present in the diet with *Rhizopogon*, *Geopora*, and *Melanogaster* the most frequently consumed genera (Stuart 2012, Johnston and others 2019). In addition to pine nuts, acorns, and Douglas Fir seeds, other foods eaten in Washington include the immature catkins of aspen, maple samaras (Bowles 1921, Scheffer 1923, 1952, Gaulke & Gaulke 1984), larval and adult rain beetles (*Pleocoma* spp.; M. Vander Haegen 2015, pers. comm.) and Oregon White Oak flowers (S. Van Leuven 2015, pers. comm.).

Other foods eaten in the southern Puget Trough include hazelnuts (*Corylus* sp.), hawthorn berries (*Crataegus monogyna*), Himalayan blackberries (*Rubus armeniacus*), epigeous (above ground) fungi, cottonwood catkins, and the cambium of Douglas-fir (Johnston and others 2019).

Home range and movements. Home ranges of Western Gray Squirrels vary in size, shape, and amount of overlap with other individuals based on sex, age, season, and the availability of food, nest cavities, and other resources. Average home range sizes vary among the three populations in Washington and are significantly larger in males (74–460 ha) than in females (18–80 ha) (Linders 2000, Linders and others 2004, Gregory 2005, Stuart 2012, Johnston 2013). These sizes are larger than those reported in Oregon and California, suggesting poorer habitat quality in Washington (Linders and others 2004). Some studies have reported that Western Gray Squirrels in Washington exhibit low same-sex home range overlap and nearly exclusive core areas (Linders 2000, Gregory 2005; Vander Haegen 2015, pers. comm.), but Stuart (2012) and Johnston (2013) documented substantial same-sex overlap (≥26%). During the breeding season, males expand their movements to search for females, whereas female movements remain similar or become more restrictive compared to the non-breeding season (Linders 2000, Linders and others 2004, Stuart 2012). Both sexes have smaller home ranges during the winter (Linders and others 2004, Stuart 2012). Animals may shift their home range locations seasonally in response to changes in the availability of food or nests or may permanently disperse to establish new home ranges (Linders & Stinson 2007). Vander Haegen and others (2005) reported that 20% of juveniles dispersed away from natal home ranges during their first fall, moving

an average distance of 2,862 ± 213 (SD) m. Stuart (2012) recorded a maximum movement of 15.4 km by an adult male.

Demographics. Vander Haegen and others (2005) reported population densities of 0.25–4.3 animals/ha in Klickitat County. Substantial population fluctuations can occur in response to changes in food supply, weather, disease, predation, and harvest of mast-bearing trees (see citations in Linders & Stinson 2007). The size of one population in southern Oregon varied 9-fold during an 8-year period (Carraway & Verts 1994). Vander Haegen and others (2013) reported a maximum life span in the wild of at least 8 years. Survival varies depending on food availability and disease outbreaks. In Klickitat County, average annual survival was higher among females (62 ± 13% [SD]) than males 55 ± 14% (Vander Haegen and others 2013). Survival is probably lowest among juveniles younger than 5 months of age. At JBLM, similar annual survival rates existed between females (60%, 95% CI 0.503, 0.697) and males (62%, 95% CI 0.454, 0.757) (Johnston 2013). Survival has been reported as being similar between breeding and non-breeding seasons (Vander Haegen and others 2013) or lower during fall-winter than in spring-summer (Stuart 2012). Equal sex ratios have been recorded in Klickitat County (Linders 2000), which is typical of most tree squirrel species (Gurnell 1987, Steele & Koprowski 2001).

Sources of mortality include predation, disease, automobiles, and sport hunting where allowed (Ingles 1947, Vander Haegen and others 2013, 2018). Western Gray Squirrel predators include raptors as well as small and mid-sized carnivores (Carraway & Verts 1994, Linders & Stinson 2007). In Klickitat County, predation by Bobcats (*Lynx rufus*), Coyotes (*Canis latrans*), and other species accounted for 63% of mortality (Vander Haegen and others 2013). Similarly, more than half of the squirrel deaths at JBLM and in the North Cascades were attributed to predation (Stuart 2012, Vander Haegen and others 2018).

Disease was responsible for 37% of Western Gray Squirrel deaths in a Klickitat County study from 1998 to 2005 (Vander Haegen and others 2013). Most (77%) of this disease mortality was due to notoedric mange caused by the mite *Notoedres centrifera*; mange was present in all years in this population and was usually most prevalent in spring (Vander Haegen and others 2013). During occasional severe outbreaks, more than half of a population can be infected, greatly reducing squirrel abundance (Cornish and others 2001, Linders & Stinson 2007, Stephenson and others 2013). To date only two cases have been detected in the North Cascades (Stuart 2012). Mild winter temperatures and nutritional stress brought on by mast crop failures, drought, or degraded habitat likely play a role in causing severe outbreaks of mange (Cornish and others 2001, Vander Haegen and others 2013). Mange has not been recorded on JBLM, but tularemia, a bacterial disease common to rodents and lagomorphs, was a mortality factor for Western Gray Squirrels on JBLM during 2007-2011, when 10 squirrels died from the disease (Vander Haegen and others 2018.).

Automobiles can be an important source of mortality (Ingles 1947), and squirrels are regularly killed by autos in all three Washington regions (Bartels 1995, 2000, Ryan and Carey 1995b, Linders & Stinson 2007, Stuart 2012, Johnston 2013), and at Oak Creek Wildlife Area in Yakima County (Gaulke & Gaulke 1984).

POPULATION AND HABITAT STATUS

Range-wide. The pre-breeding season population size of Western Gray Squirrels in California was estimated at approximately 18 million animals (California Department of Fish and Game 2002, *in* USFW 2003). The species is hunted in most of the northern two-thirds of California, with up to 50,000 squirrels harvested annually (CDFG 2011). Population data are lacking for Oregon. The species showed some evidence of decline in recent decades, particularly in the north (Foster 1992, Weston 2005), but recent observations suggest abundance has perhaps stabilized and that distribution has expanded eastward in some areas of the state (T. Thornton 2015, pers. comm.). Hunting is still allowed in Oregon, but harvest levels are not recorded; it is listed as "sensitive" in the Willamette Valley (ODFW 2021). It is a "protected species" in Nevada, is uncommon and not hunted (USFWS 2003). Population status in Mexico is unknown.

Washington past. Relatively little information is available on the historical abundance of Western Gray Squirrels in Washington (Linders & Stinson 2007). The species was noted as uncommon in the southern Puget Trough during the late 1800s due to hunting but increased substantially after about 1910 (probably because of legal protection and increased forest availability) and was described as "extremely numerous" in 1921 (Bowles 1921). Booth (1947) remarked that squirrels in western Pierce County were more common than in Klickitat County. Records indicate that Western Gray Squirrels remained fairly widespread in Pierce and Thurston counties into the 1970s (Barnum 1975; WDFW WSDM database), although land development caused declines in some areas in the 1950s or earlier (M. Johnson, pers. comm. *in* Rodrick 1986). Squirrels were last recorded in southern Thurston County during the late 1970s (WDW 1993). By 1985, the southern Puget Trough population appeared to be restricted to JBLM (Rodrick 1986).

Western Gray Squirrels were uncommon to locally common in the southern Cascade Mountains in the 1930s and 1940s (Booth 1947, Scheffer 1957). Anecdotal reports indicate that outbreaks of mange decimated numbers in Klickitat County in the 1930s (Linders & Stinson 2007) and in Yakima County in the 1940s-1950s (Stream 1993). The species was considered uncommon in parts of Klickitat County during the 1970s (Barnum 1975; D. Morrison, pers. comm. *in* Linders & Stinson 2007).

Observations are sparse for the North Cascades population, but a hunting season for the species was closed in 1929 after one year, apparently because squirrels were insufficiently abundant (Linders & Stinson 2007). Hard winters and indiscriminate shooting may have kept numbers relatively low during the 1960s (Stream 1993, WDFW files).

The Western Gray Squirrel was included in a 1970 brochure of rare mammals in Washington, when it was described as most numerous in oak woods, but scarce elsewhere in its range (Lauckhart 1970). Barnum (1975) stated that the species had become increasingly rare and that remaining populations were restricted to a few isolated locations in the state.

Washington present. Linders & Stinson (2007) summarized survey efforts conducted for Western Gray Squirrels in Washington from the early 1990s to 2005. They estimated the number of animals in each of the three populations based on the amount of potential habitat, distribution of squirrel occurrences, average

home range sizes, and typical home range overlaps. Estimates of hypothetical population size were 705, 190, and 42 squirrels for the Klickitat, North Cascades, and southern Puget Trough populations, respectively. The statewide total for 1994-2005 was believed to be between 468 and 1,405 squirrels (937 ± 50%). No new population estimates have been derived for Western Gray Squirrels in Washington since the 1994-2005 estimate by Linders & Stinson (2007).

Research, surveys, and habitat changes since 2005 provide some information that would affect the estimates and the current population size in the southern Puget Trough. For example, WDFW conducted a translocation project from 2007 to 2012 to improve the genetic diversity of the squirrel population on JBLM, releasing 93 animals from other populations in Washington and Oregon (Vander Haegen & Orth 2022). Additionally, recent research indicates that home range overlap on JBLM may be greater than previously reported (Johnston 2013), which could indicate a larger population size. Ongoing habitat enhancement of oak communities has likely also benefited this population. Based on recovery efforts and new information, this population is presumed larger now than in 1994-2005 and may occupy a somewhat larger area, including a few individuals living outside of JBLM in both Pierce and Thurston counties (Vander Haegen & Orth 2011; M. Vander Haegen 2015, pers. comm.). However, the population is still considered vulnerable because of its small size, limited geographic range, and isolation from other populations (Vander Haegen and others 2018).

Three recent data sources indicate that until June 2014 the North Cascades population was probably also larger than estimated by Linders & Stinson (2007). Stuart's (2012) telemetry data suggested smaller home ranges and greater overlap among squirrels than noted by Gregory (2005), indicating that available habitat in some areas supported more animals than previously believed. Genetic analyses also suggested that the region had a larger effective population size than previously thought (i.e., 500-1,000 squirrels), although this estimate has not been validated with field data (Stuart 2012). Surveys conducted along the Methow and Okanogan Rivers in 2010-2013 slightly expanded the known distribution of the species (Yamamuro and others 2011, Pacific Biodiversity Institute 2012).

Factors suggesting changes in the size of squirrel populations in all three regions since Linders & Stinson (2007) include a slight increase in the southern Puget Trough due to augmentation and habitat conservation on JBLM, a decrease in numbers and distribution in the North Cascades resulting from major forest fires, and a likely decrease in the Klickitat region due to habitat alteration and loss. Periodic trapping on a 1-km^2 grid in good quality habitat on the Klickitat Wildlife Area suggested squirrel abundance remained relatively stable there from 2000-2015 (M. Vander Haegen 2015, pers. comm.). No major outbreaks of mange have been reported in the population since 1999 (M. Vander Haegen 2015, pers. comm.).

Occupancy surveys. Initial population sizes estimated by Linders & Stinson (2007) relied on location data collected over more than a decade and using a variety of techniques (surveys, incidental observations, road kills, etc.) and as such were not repeatable. Subsequent efforts to develop an alternative method for estimating squirrel density and abundance based on trapping grids proved onerous and expensive and

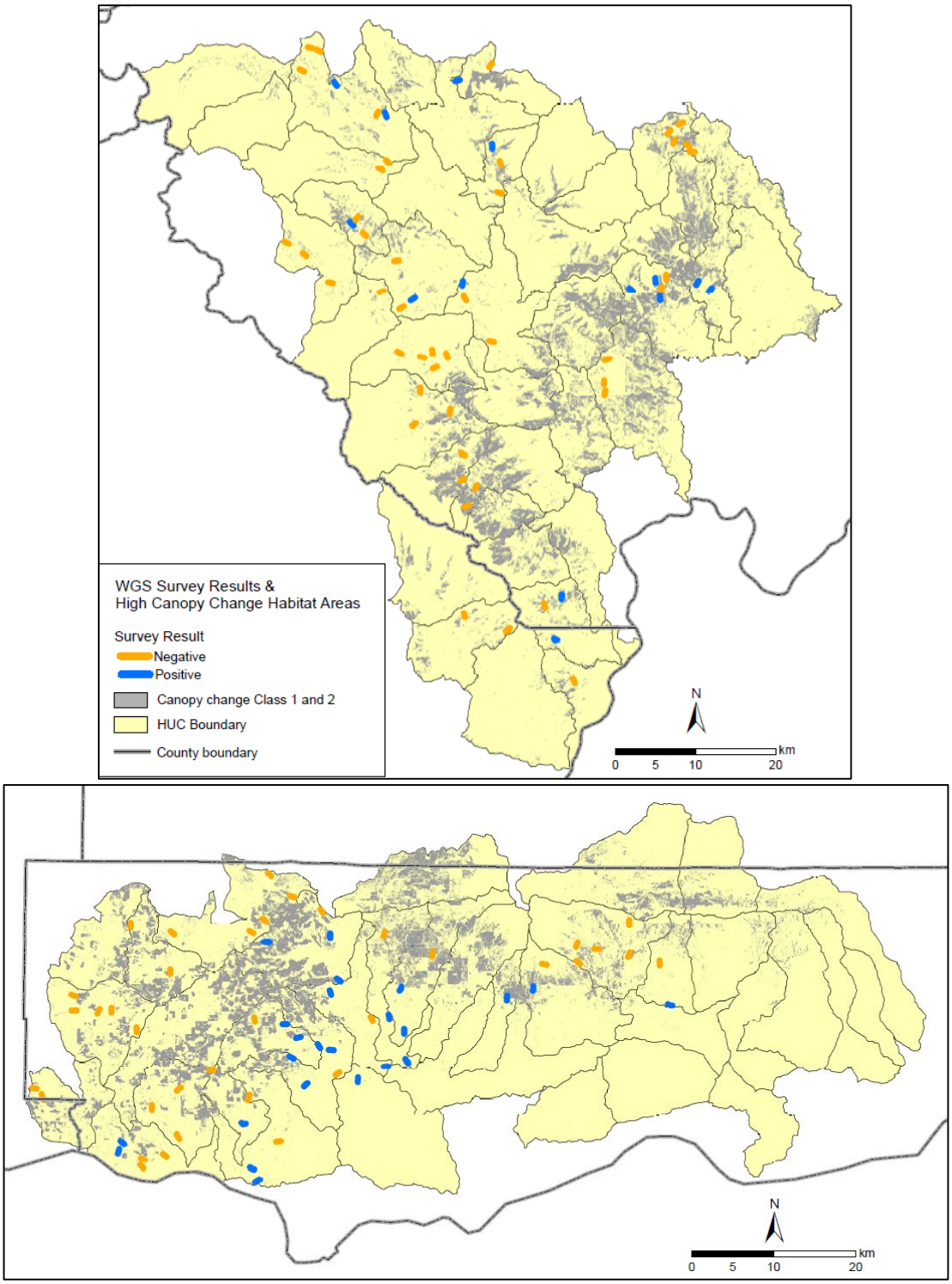

Figure 3. Occupancy survey results for the North (top) and South (bottom) Cascades overlaid on the two largest habitat loss classes from the habitat change analysis (canopy change classes 1 and 2) conducted by Vander Haegen and others (2022).

would be difficult to apply range-wide. Alternatively, an occupancy survey methodology using hair tubes was developed in 2015-2017. In 2018-2020 surveys were conducted in each of three geographic core areas

to establish occupancy rates for Western Gray Squirrels. The results will serve as a baseline for assessing the species' prevalence on the landscape and detecting trends in occupancy in coming years (Vander Haegen & Keren 2021). Repeated over time, the surveys can identify changes in occupancy level among areas surveyed. The surveys utilized hair snag tubes deployed in arrays to account for detection probability in estimates of occupancy rates.

Twelve hair tubes, arranged in three clusters along a 600-m transect, were deployed for each survey in suitable habitat. Desired stand characteristics were: 1) a conifer-dominated overstory of mature trees (primarily Douglas fir or ponderosa pine) or mixed stands of conifer and Oregon oak, with oak comprising <50% of the overstory; 2) tree canopy closure of ≥40% (averaged for the site); 3) large (≥16 in dbh) conifer trees present in the stand; 4) shrub cover <50%; and 5) open ground ≥10%. Stand characteristics were estimated during preliminary scouting and later quantified at each point when tubes were deployed. Employing data from 138 transects (18 in the Puget Trough and 60 each in the North and South Cascades), modeled occupancy rates were 0.39 (SD = 0.12) for the Puget Trough, 0.27 (0.06) for the North Cascades, and 0.44 (0.07) for the South Cascades (Klickitat). Conditional detection probability was high (0.91, SE = 0.03) indicating that squirrels were generally detected when present on a site. In the North Cascades, positive detections occurred in isolated pockets across the sampling area, whereas in the South Cascades detections were notably lacking in peripheral areas throughout the sampling distribution (Fig. 3). Both patterns are consistent with range decay. In the southern Puget Trough, occupied transects were interspersed with unoccupied transects across the sampling area. Peripheral areas with suspected low density of squirrels were not included in occupancy surveys because previous efforts to assess populations in these areas were costly and unproductive due to very low detection rates.

Habitat changes. WDFW evaluated changes in availability of primary habitat (Linders and others 2010) for Western Gray Squirrels in the North and South Cascades between 1993 when the species was listed and 2017, as well as the relative contribution of different drivers of habitat change (Vander Haegen and others 2022). Habitat with the potential to support squirrels was first identified based on ecological systems and elevation range to produce analysis areas of 3,765 km^2 for the North Cascades and 3,379 km^2 for the South Cascades. Within each footprint areas of change in tree canopy cover were identified at a meso-scale using a published raster dataset, then further analyzed using orthophoto sequences for >1,000 random plots in each region. Plots characterized as primary habitat had at least 40 percent canopy cover and were composed of large trees (>9" dbh for conifer, >5" dbh for oak) with some larger trees present as nest trees.

Results from this analysis suggest that gains in primary habitat from successional processes (e.g., tree recruitment and tree growth) did not compensate for loss of primary habitat during the analysis period. The estimated net loss of primary habitat totaled 20.8% (0.9 SE, 19.0–22.6 95% CI) for the North Cascades and 21.2% (1.2 SE, 18.8–23.6 95% CI) for the South Cascades (Vander Haegen and others 2022). Wildfire was the dominant disturbance in plots examined in the North Cascades while timber harvest was the dominant disturbance in the south Cascades. Tree mortality from disease or insect infestation was suspected in 4 of 14 plots where cause of habitat loss was classified as unknown.

The total area of potential Western Gray Squirrel habitat in wildfire perimeters was 146,965 ac (59,500 ha) in the North Cascades (Fig. 3), and 22,724 ac (9,200 ha) in the South Cascades. In the North Cascades, the 2014 Carlton Complex fire (>250,000 ac) burned large areas of squirrel habitat, including areas where squirrels have been sighted consistently for decades (WDFW WSDM database). This was followed in 2015 by the 304,782 ac Okanogan Complex, the ~89,000 ac Chelan Complex, and the 65,000 ac Wolverine fires that all burned additional potential squirrel habitat. Additional squirrel habitat burned in 2018 during the ~52,000 ac Crescent Mtn and ~23,000 ac McLeod fires. Then in 2021 the ~70,000 ac Cub Creek 2, ~55,000 ac Cedar Creek, ~13,000 ac Muckamuck, and ~6,000 ac Chickadee Creek fires consumed large areas of potentially occupied habitat. Sizeable areas of habitat burned at high or moderate intensities in these fires, likely rendering habitat unsuitable for decades and potentially killing squirrels.

Removal of overstory trees for commercial and non-commercial purposes occurred over large portions of both project areas, but the type of forest management differed between the North and South Cascades. Partial canopy removal through thinning accounted for all harvest plots in the North, but 45% of harvested plots in the South were clear-cut (Vander Haegen and others 2022). The total area of potential squirrel habitat within forest practice polygons in the North was 48,600 ac (19,676 ha); 22.7% occurred on federal and 77.3% on state and private ownership. In the South Cascades, where most of the squirrel habitat occurs on private lands, timber harvest (Fig. 4) was responsible for the greatest loss of potential habitat. Extensive areas of Douglas-fir and Ponderosa Pine forest in the South Cascades have been clear-cut or thinned below canopy levels usable by Western Gray Squirrels and recent surveys for squirrels in these areas found low occupancy, even though surveys were focused on remaining patches of suitable habitat. The total area of potential Western Gray Squirrel habitat within forest practice polygons in the South was 103,650 ac (41,962 ha) and all occurred on state or private lands (Vander Haegen and others 2022). The typical pattern of thinning, with trees spaced evenly and few clumps or skip patches, would be expected to lengthen the time needed to achieve suitable canopy connectivity, which is essential for Western Gray Squirrel habitat. In areas of eastern Klickitat County, canopy loss through thinning was so extensive that it was difficult to locate remnant patches suitable to conduct occupancy surveys (Vander Haegen & Keren 2021).

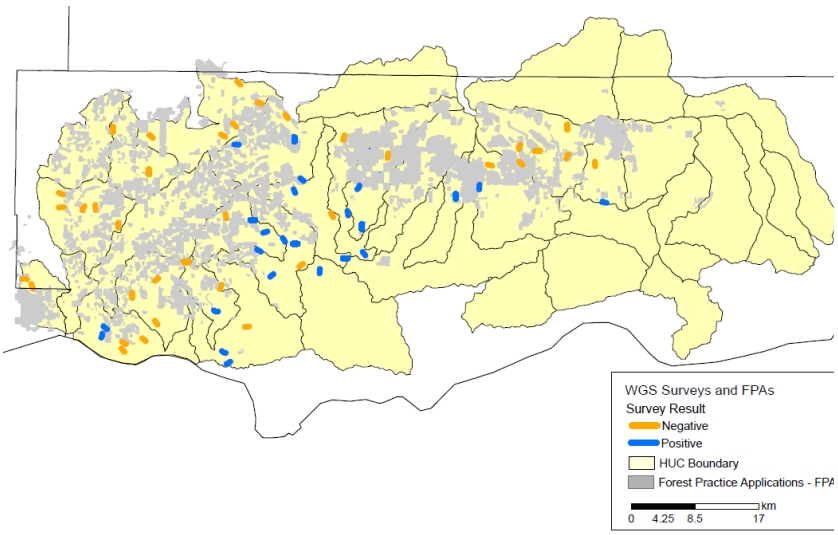

Figure 4. Areas issued permits for timber harvest in the South Cascades (Klickitat) analysis area (gray shade), 2003-2017 (Vander Haegen and others 2022).

FACTORS AFFECTING CONTINUED EXISTENCE

Adequacy of existing regulatory mechanisms. As a state threatened species, Western Gray Squirrels are protected from intentional killing and intentional destruction of nests (RCW 77.15.130). However, there is no Forest Practices Rule in effect that would restrict timber harvest to accommodate Western Gray Squirrel habitat needs. Instead, the Washington Department of Natural Resources (WDNR) and WDFW have taken a voluntary management approach with forest landowners to protect squirrel habitat. WDFW biologists screen Forest Practices Applications (FPAs) for potential Western Gray Squirrel habitat and conduct pre-harvest nest surveys to confirm presence or absence. While demonstrating occupancy of squirrel habitat currently relies upon finding stick nests, there are drawbacks to this method, including (1) telemetry has revealed that some stick nests may not be detected during surveys, (2) occupancy surveys may fail to identify forest stands used only for foraging or those having only cavity nests, and (3) some sites inhabited during periods of moderate to high population densities may be temporarily unoccupied during periods of lower abundance, and deemed unoccupied during pre-harvest survey, leading to habitat loss.

At sites where squirrel occupancy is confirmed, biologists work with landowners to educate them about the species, its habitat requirements, and how WDFW's Priority Habitats and Species (PHS) recommendations (Linders and others 2010) can be incorporated into harvest planning and land management goals. Together they develop a voluntary management plan they voluntarily agree to implement, that strives to provide protection for the squirrel and its habitat. The level of habitat protection in any given plan varies depending on (1) the landowner's harvest goals, (2) the level of squirrel occupancy, and (3) the landowner's willingness to incorporate WDFW's recommendations. Plans are shared with the WDNR, who may assist with implementation. In a study of 10 timber harvest sites in Klickitat County, Vander Haegen and others (2004) found that operators did not always implement all of the recommended protection measures specified in the forest practices permits. All sites except one had active nests during the resurvey, suggesting that Western Gray Squirrels continued to use the sites at some level 1-3 years post-harvest, although occupancy was not an objective of the study. They concluded there was a strong need to improve implementation of habitat protection measures and suggested a more controlled research approach was needed to evaluate changes in demography as a function of harvest patterns.

In 2013, the Forest Practices Board requested that WDFW and WDNR provide annual reports on the status of Western Gray Squirrels, management plans developed for their protection, and the effectiveness of the current voluntary management approach. As of 2022, annual reports summarizing the number of FPAs and status of WDFW's survey and management actions have been provided. In addition, the Forest Practices Board received the 2016 Western Gray Squirrel Periodic Status Review, which stated that data needed to inform a change in status were lacking and no new information has been provided until now. Between 2014 and 2021, 629 FPAs required additional review for Western Gray Squirrels, including surveys and/or protection measures. Most plans incorporated the agreed upon protection measures, however in any given year 0-7 voluntary management plans were not meeting the level of habitat protection recommended by biologists (primarily leaving only nest trees without adequate connectivity). All were small forest landowners. The WDNR and WDFW are increasing their outreach to small forest landowners on the importance of their participation in providing habitat conservation for the squirrel, and in contributing to

the greater voluntary management approach. While Habitat Program efforts to tally FPAs and plans is admirable and useful, due to funding and staff constraints there has been no (or very little) follow-up to evaluate whether plans are implemented as designed or to document their efficacy as squirrel habitat.. When more information is available, the Forest Practices Board will assess whether additional protection measures may be necessary.

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, implementation, and levels of protection offered, but generally development proposals impacting the habitat of a listed species can be conditioned to avoid, minimize, or mitigate impacts. For projects involving the cutting of oaks and other large trees used by Western Gray Squirrels, effective mitigation is difficult because it takes decades for replacement trees to get large enough to produce mast in significant amounts and/or to develop suitable structures for nesting. Pierce, Thurston, Okanogan, Chelan, Klickitat, and Yakima counties have critical area ordinances that apply where Western Gray Squirrels or their habitat are known to occur.

Federal protective measures for Western Gray Squirrels in Washington vary among agencies. The species is recognized as a "sensitive species" by the U.S. Forest Service, but this classification provides no protection for animals and little protection for their habitat. Western Gray Squirrels may receive some consideration in Forest Service 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, which is jointly administered by the Columbia River Gorge Commission and the U. S. Forest Service, protects confirmed Western Gray Squirrel nests and requires WDFW-approved plans for development or timber harvest where the species is present. At JBLM, policy or guidelines for management of the species is contained in the base's *Integrated Natural Resources Management Plan* (DOA 2019).

Although not a federally listed species, Western Gray Squirrels are included in the WDNR Final Habitat Conservation Plan (HCPs) approved by the U.S. Fish and Wildlife Service, as a species that would benefit from protection of oak woodlands. Although the HCP's primary focus is western Washington, some aspects of oak woodland habitat (e.g., trees >20 inches [51 cm] in diameter and maintenance of 25–50% canopy cover) are also protected in South Cascades planning units during WDNR operations (WDNR 1997). The riparian conservation strategy also provides some habitat protection. When consistent with trust objectives, WDNR policy is to voluntarily work with state agencies on efforts to protect Western Gray Squirrels (WDNR 2006); WDNR managers in their SE region have cooperated with WDFW in developing management plans in occupied stands (G. Bell 2022, pers. comm.).

Habitat loss, degradation, and fragmentation. Conifer-hardwood forests in Washington have changed dramatically over the past century and continue to be negatively impacted by land conversion, timber harvest, wildfire, and fire exclusion (Chappell and others 2001a, 2001b). All three Western Gray Squirrel populations are affected by various forms of land development (e.g., building and road construction, land clearing), resulting in ongoing habitat loss and fragmentation for the species. Along the eastern Cascade

Mountains, development is often concentrated in the riparian forests of valley bottoms occupied by squirrels contributing to landscape-scale fragmentation (USDA Forest Service 1996). Development continues to accelerate in the southern Puget Trough on lands surrounding JBLM, reducing opportunities for Western Gray Squirrel colonization areas outside the base. On JBLM, loss of potential primary habitat has occurred incrementally as forest is cleared for new buildings and other infrastructure; however, this loss to development may be offset somewhat by habitat restoration activities elsewhere on the base.

Timber harvest often degrades Western Gray Squirrel habitat by destroying nests and potential nest sites, fragmenting the tree canopy that squirrels use for travel, and reducing or eliminating food sources (Vander Haegen and others 2004, Linders & Stinson 2007). Some level of thinning harvest may improve forest conditions for squirrels by increasing sunlight to remaining trees and increasing mast production, but more typically over-thinning reduces canopy closure, inhibiting arboreal travel and increasing exposure to predation. Among the three Western Gray Squirrel populations in Washington, timber harvest activities have been most active in the Klickitat region and have contributed towards an estimated 21% net reduction in primary habitat for the species since its listing in 1993. In 2014-2021, 566 of 629 FPAs (91 percent) requiring review for Western Gray Squirrels were in Klickitat County (WDFW, unpub. data). On average, small landowners filed 12.1 ($\pm$8.7 SD) plans per year compared to 28.4 ($\pm$21.5 SD) by large landowners. In 2020, 79 FPAs in squirrel habitat were filed by large landowners, eight standard deviations above the average for the remainder of that period. In Okanogan County, FPAs increased substantially after the 2014 and 2015 wildfires as landowners salvaged burned stands or thinned stands outside the perimeter of the fire (Vander Haegen and others 2022, G. Bell 2015, pers. comm.).

Wildfires and fuel treatments. Fire suppression in the 20th Century, particularly in the drier forest of the eastern slope of the Cascades increased tree density, litter depth, fuel loading, and invasion by Grand Fir (*Abies grandis*) (Agee 1993, Lehmkuhl and others 1994, Graham & Jain 2005). At more mesic sites, this can lead to overtopping and suppression of shade-intolerant oaks and pines (Agee 1993, Ryan & Carey 1995a). These changes have increased the risk of large catastrophic wildfires that threaten Western Gray Squirrels and their habitat. Fuel treatments and regular prescribed burns of lower intensity can help restore forests to conditions more typical of the historical period prior to fire suppression to which the squirrel is adapted. Benefits include reducing the density of forest understories, creating more open park-like conditions in forests, enhancing the survival and size of remaining trees, increasing seed production, as well as reducing the potential for large destructive fires (Agee 1993, Fitzgerald 2005). However, fuel reduction projects can also negatively alter squirrel habitat and affect populations (Lehmkuhl and others 2004, Stuart and others 2018). Fuel reduction treatments are essential for preventing large stand-replacing wildfires and include prescribed burning, mechanical thinning, and removal of ladder fuels. These actions can result in a less complex and more open canopy, lower diversity of canopy tree species, reduced availability of mistletoe brooms that squirrels often use as nest sites, and a drier microclimate resulting in lower biomass of truffles (Lehmkuhl and others 2004, Stuart and others 2018). Negative impacts to squirrel habitat from fuel reduction treatments can be reduced, for example, by limiting removal of mistletoe brooms to the lower third of the tree which reduces ladder fuel and retains nesting and resting structures for squirrels (Stuart and others 2018).

Small population size and isolation. Small, isolated populations of Western Gray Squirrels, such as those found in Washington, face higher risks of extirpation from stochastic events (e.g., disease outbreaks, fluctuations in mast production) and declining genetic diversity that can result in inbreeding depression and reduced fitness. Washington populations are known to have lower genetic diversity than populations in Oregon and California (Warheit 2003). By the early 2000s, the southern Puget Trough population was considered most at risk from genetic concerns because of its small size. While translocation of 93 animals from other populations in Washington and in Oregon to JBLM have increased genetic diversity (at least temporarily), population modeling based on empirical data on survival and reproduction suggest that population remains at risk (Vander Haegen and others 2018).

Disease. Notoedric mange has had a significant impact on Western Gray Squirrels in the Klickitat population since at least the early 1930s (Linders & Stinson 2007) and was the second most common cause of mortality after predation (Vander Haegen and others 2013). Mange outbreaks are occasionally severe and have caused declines in squirrel abundance but have been reported only rarely in the North Cascades and not at all in the southern Puget Trough populations. Outbreaks likely result from periods of nutritional stress caused by mast crop failures, drought, or degraded habitat (Cornish and others 2001, Linders & Stinson 2007) and may be related to mild winters (Vander Haegen and others 2013). Outbreaks have not been observed in the Klickitat population since 1999 but remain a recurring threat in this region (Vander Haegen and others 2013). Tularemia was a significant cause of mortality in a study population on JBLM (Vander Haegen and others 2018); however, prevalence of this disease in other populations and frequency of occurrence is unknown.

***Road mortality*.** Squirrels in all three Washington populations have experienced significant roadkill mortality (Linders & Stinson 2007). Animals often traverse roads to access foraging sites or when seeking mates, which can expose them to vehicles on a regular basis (Linders & Stinson 2007). Immature squirrels may be most vulnerable, especially when dispersing from their natal home range (Gaulke & Gaulke 1984, Ryan & Carey 1995b). The risk of road-kill mortality is expected to increase in the future as Washington's human population and hence traffic volume, continues to grow.

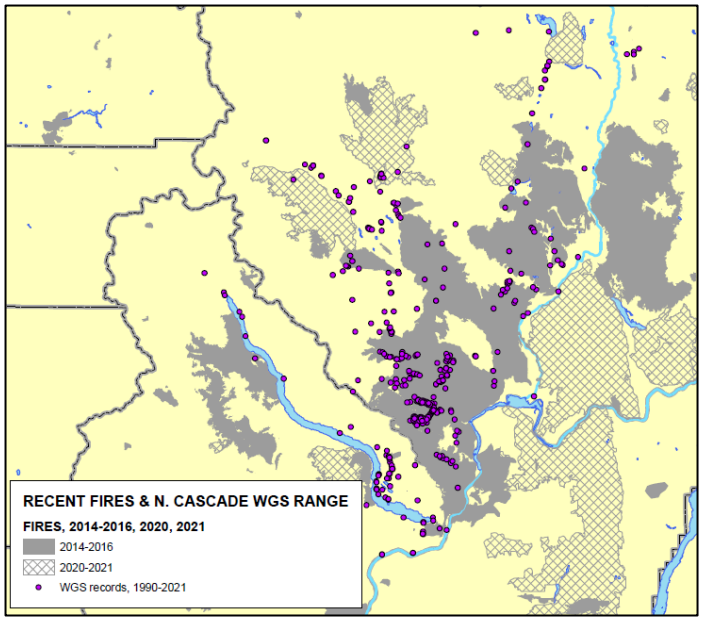

Figure 5. Recent wildfires and Western Gray Squirrel records in the North Cascade region.

Climate change. Future impacts of climate change on Western Gray Squirrels in Washington are unclear, especially over the long-term. Altered fire regimes caused by climate change have probably already affected the occurrence and intensity of

forest fires in the state, with impacts likely to increase in the future (Littell and others 2010). For example, in the eastern Cascade Mountains of Washington, area burned by high-severity fire is 4-10 times that of historical fire regimes and was most divergent in dry vegetation zones which were historically characterized by low severity (ponderosa pine) and mixed severity (Douglas fir and grand fir/white fir) fire regimes (Reilly and others 2017). Major fires are capable of damaging or destroying large areas of Western Gray Squirrel habitat and directly killing squirrels, as demonstrated in Okanogan and Chelan Counties in recent years. Under a medium greenhouse gas scenario, the area of climate suitability for Douglas-fir is projected to decline over 32 percent by the 2060s, especially in the Okanogan Highlands and southern Puget Trough (Snover and others 2013). Under the same scenario, 85 percent of the current range of Ponderosa, lodgepole and whitebark pine is projected to become unsuitable for one or more of the three species. Drier, warmer summers are also expected to increase risk of insect and disease outbreaks. Additionally, warmer temperatures associated with climate change could increase the exposure of squirrels to disease (Steel and others 2011). While, one recent modeling exercise suggests Western Gray Squirrels could significantly expand their eastward range in Washington as climate change alters the distribution of forests over the next century (Johnston and others 2012), such changes will depend on seed production, tree recruitment and climate variability, including extreme events and changing levels of atmospheric CO2 and nitrogen fertilization (Hacket-Pain and Bogdziewicz 2021).

Competition with introduced species. Introduced Eastern Gray Squirrels (*S. carolinensis*) and Eastern Fox Squirrels (*S. niger*), and native California Ground Squirrels (*Otospermophilus beecheyi*) may compete for food and habitat with Western Gray Squirrels in parts of their range in Washington (Linders & Stinson 2007). These species are expanding their ranges in Washington and overlap in places with Western Gray Squirrels in the southern Puget Trough or in parts of Okanogan, Chelan, Yakima, Klickitat, and Skamania counties. Recent research at JBLM detected few competitive interactions between western and eastern gray squirrels largely because of differential habitat use (Johnston and others 2020). This pattern may not hold true in other locations where Western Gray Squirrels and introduced squirrels may occupy the more similar habitats. Introduced Wild Turkeys (*Meleagris gallopavo*) are another potential competitor of Western Gray Squirrels. Although there are no data on the potential impacts of turkeys on Western Gray Squirrels, the two species overlap extensively in the Klickitat and Okanogan regions and are known to consume some of the same foods (Linders & Stinson 2007).

Other human-related or natural factors. Other factors may have the potential to negatively affect Western Gray Squirrels in Washington but have not yet been confirmed to have important impacts to populations. These include disturbance from military training exercises at JBLM, poorly managed grazing practices, incidental hunting mortality, and introduced pathogens or insects that harm squirrel habitat (Linders & Stinson 2007, Linders and others 2010). Barred owls are also a potential new threat, having expanded their range into Washington state. Weins and others (2014) found barred owls consumed a high frequency of diurnal prey rare or absent in diets of spotted owls, including Western Gray Squirrel, and expanding populations have the potential to trigger a trophic cascade.

MANAGEMENT ACTIVITIES

Management recommendations. WDFW updated its PHS management recommendations for Western Gray Squirrels in 2010 (Linders and others 2010). These revisions included a shift in emphasis from protecting individual nest locations and maintaining forest canopy connectivity between nest trees, to a broader landscape-level approach focused on protecting key habitat features important for Western Gray Squirrels.

Management plans for forest practice applicants. WDFW Habitat Program staff regularly review FPAs that may adversely impact Western Gray Squirrels or their habitat (see Adequacy of Existing Regulatory Mechanisms). For willing landowners with squirrels on their lands or proposed harvest sites, staff work with landowners to develop management plans that incorporate PHS recommended habitat protection measures for squirrels. Landowners that voluntarily accept a plan agree to minimize harvest activities that alter habitat and that may disrupt breeding and the rearing of young. The level of protection agreed to and implementation in these management plans, however, varies depending on the landowner's forest management goals and financial constraints. Compliance with these voluntary agreements is rarely examined post-harvest.

Surveys. WDFW and partners continue to survey for Western Gray Squirrels to determine current distribution in Washington and to inform forest practices. Surveys for distribution are primarily conducted using hair-snag tubes to confirm species presence, whereas forest practices surveys focus on the location of nest structures. The Pacific Biodiversity Institute conducted hair-tube surveys in the Methow watershed of Okanogan County in 2010-2012. This citizen science project resulted in the deployment of tubes at 463 sample locations and detections of squirrels at 44 locations, including five new areas (Pacific Biodiversity Institute 2012). In 2010-2012 WDFW conducted additional hair-tube surveys at other locations in the North Cascades. These included sites with squirrel habitat along the south shore of Lake Chelan in 2010 and 2011 (106 tube locations, squirrel detections in multiple new drainages; Gallie 2010); along the north shore of Lake Chelan and the Entiat River valley in 2012 (37 tube locations, no detections); in the Okanogan watershed (no detections); and in the Nile Creek drainage in Yakima County in 2011 (20 tubes, no detections) after a Western Gray Squirrel was photographed nearby. Within the scope of forest practices, Western Gray Squirrel nest surveys may be triggered when the location of a FPA submitted to DNR occurs within 0.5 miles of a documented squirrel occurrence (biotic detection or nest location), and/or within the area mapped by WDFW as potential habitat (PHS polygon). When such FPAs are identified, a WDFW biologist further reviews available information (GIS data, orthoimagery, etc.) to determine if a site visit and/or nest survey is required. Nest search surveys are conducted within suitable habitat, and all nest locations and squirrel detections are documented and added to WDFW's WSDM database. Data are used to screen for other FPAs that may warrant nest surveys and to inform site-based management recommendations for landowners.

Southern Puget Trough population augmentation. WDFW, in cooperation with JBLM, conducted a translocation project from 2007 to 2012 to augment the Western Gray Squirrel population on base, releasing 93 animals from Klickitat and Okanogan counties and from Hood River and Wasco counties,

Oregon (Vander Haegen and Orth 2022). Goals of the project were to increase the population's size, genetic diversity, and occupied area. The project was considered successful, with breeding populations established in two new areas of the Base. Translocated animals showed levels of survival and reproductive success comparable with those of squirrels in the larger, South Cascades population and were likely interbreeding with resident squirrels (Vander Haegen and Orth 2022).

Research. Several research projects have been conducted since 2007 that have provided valuable information on the species' conservation and management in Washington. In the North Cascades, Stuart (2012) studied distribution, life history, and response of Western Gray Squirrels to fire fuel treatments during 2008-2011. Core areas and nest sites were located in both treated and untreated sites, indicating that previous fuel treatments retained adequate habitat to support squirrel populations in this area. Stuart (2012) recommended that during fuels reduction treatments, desirable habitat features such as patches of large trees with mistletoe and moderate levels of canopy cover and connectivity should be retained to protect habitat for squirrels. The study also found similar genetic heterozygosity and allelic richness between the Methow Valley and Stehekin subpopulations.

Two intensive studies of Western Gray Squirrel ecology were conducted on JBLM in 2006-2012. The first quantified population parameters including survival, causes of mortality, productivity, and resource selection (Vander Haegen & Orth 2009, 2011, Vander Haegen and others 2018), while the second examined potential competition between Western and Eastern Gray Squirrels (Johnston 2013, Johnston and others 2019, 2020). The latter study noted high dietary overlap for most food resources between the two species but found little distributional overlap in terms of habitat use. Western Gray Squirrels occurred primarily in coniferous uplands with little understory vegetation, whereas Eastern Gray Squirrels used riparian areas with deciduous trees and dense understory. Johnston (2013) concluded that coexistence of western and eastern gray squirrels appears possible where distinctly different upland and riparian habitats occur.

Other management activities. Habitat restoration, done in part to benefit Western Gray Squirrels, has been conducted at several locations. At JBLM, restoration of oak communities is underway and involves the removal of Douglas-fir trees overtopping oak stands, mowing of Scotch broom, and planting of oak seedlings. At the Klickitat Wildlife Area, forests have been thinned as resources allow to reduce the threat of large wildfires and eliminate excessive ground cover for squirrels. Fire fuel reduction treatments with Western Gray Squirrels in mind have also been conducted by the National Park Service at Stehekin and by WDFW in the Sinlahekin. In fall 2021, The Conservation Fund purchased 29,800 acres in western Klickitat County previously held by SDS Lumber Company. Their initial land management focus is on protection and enhancement of the health and resilience of these forests, particularly in the oak-pine interface, with variable retention thinning completed across 860 acres in 2022 (E. Smith, pers. Comm. 2023).

CONCLUSIONS AND RECOMMENDATION

Western Gray Squirrels have declined substantially in Washington since the late 1800s and are now largely limited in distribution to three separate areas: the Klickitat region, the North Cascades, and the southern

Puget Trough. Population estimates have not been updated since 1994-2005, when Linders & Stinson (2007) estimated 937 ± 50% (low of 468, high of 1,405) squirrels in the state. Since 2005, abundance has probably increased somewhat in the southern Puget Trough because of translocations, although this population remains insecure because of its small size and limited geographic area. Recent analysis indicates the availability of the squirrel's primary habitat in both the North Cascades and Klickitat regions has decreased >20% since listing, continuing a downward trend that prompted listing of the species as threatened in 1993. Western gray squirrels in Washington continue to be most threatened by habitat loss, degradation, and fragmentation; small population size and isolation; disease; and roadway mortality.

Due to limited information on population abundance of squirrels, the recovery plan established a recovery objective for downlisting from threatened to sensitive but did not establish a population objective for uplisting to endangered status (Linders & Stinson 2007). Because of the species' relatively small total population size, isolation and fragmentation of the three populations, continuing threats of wildfire and timber harvest, and continuing trend in loss of primary habitat in both the North Cascades and Klickitat regions it is recommended that the Western Gray Squirrel be uplisted to a state endangered species in Washington.

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The references cited in the *Periodic Status Review for the Western Gray Squirrel* are categorized for their level of peer review pursuant to section 34.05.271 RCW, which is the codification of Substitute House Bill 2661 that passed the Washington Legislature in 2014. A key to the review categories under section 34.05.271 RCW is provided in Table A. References were categorized by the author.

Table A. Key to 34.05.271 RCW Categories:

34.05.271(1)(c) RCW	Category Code
(i) Independent peer review: review is overseen by an independent third party.	i
(ii) Internal peer review: review by staff internal to the Department of Fish and Wildlife.	ii
(iii) External peer review: review by persons that are external to and selected by the Department of Fish and Wildlife.	iii
(iv) Open review: documented open public review process that is not limited to invited organizations or individuals.	iv
(v) Legal and policy document: documents related to the legal framework for the significant agency action including but not limited to: (A) federal and state statutes; (B) court and hearings board decisions; (C) federal and state administrative rules and regulations; and (D) policy and regulatory documents adopted by local governments.	v
(vi) Data from primary research, monitoring activities, or other sources, but that has not been incorporated as part of documents reviewed under the processes described in (c)(i), (ii), (iii), and (iv) of this subsection.	vi
(vii) Records of the best professional judgment of Department of Fish and Wildlife employees or other individuals.	vii
(viii) Other: Sources of information that do not fit into one of the categories identified in this subsection (1)(c).	viii

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PERSONAL COMMUNICATIONS

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APPENDIX A. Public Comments

Report Section	Comment and Response
Population and Habitat Status	1. There was no field verification of the orthophoto interpretation. Expert opinion that was used is subjective.
	The objective for incorporating the orthophoto interpretation was to identify the nature (gain/loss) and source of canopy change found in the raster data set developed at Oregon State University. For this our ortho expert assessed canopy cover, tree size, and canopy connectivity to determine whether each 1-ha plot area qualified as habitat or not habitat. This was not a subjective method, although some variation in precision may be expected. In addition to the end dates (1993/5 and 2017) we used imagery of intermediate age to address occasional uncertainties around the cause of habitat loss and/or timing. In addition we included more 1-ha plots for review in areas where habitat gain or loss were less clear based on smaller percentages of canopy change in the OSU raster data set.
	2. Occupancy surveys were put in areas suspected of high Western Gray Squirrel use, and did not overlap areas that were estimated to experience canopy cover change.
	The objective of the occupancy surveys was to determine what proportion of primary habitat was occupied within the core parts of the species range. We sampled primary habitat because these are the parts of a squirrel's home range where the most time is spent. As such, survey transects were placed in stands that appeared to meet the definition of primary habitat first by consulting aerial photos, and then by confirming the placement of those transects on the ground. We conducted the occupancy assessment at the HUC scale. Because this study was focused in primary habitat where squirrels are most likely to be detected, areas of high canopy loss would not have met the study criteria.
	3. There is no verification that decline in habitat has resulted in decline in Western Gray Squirrels.
	This is true. The occupancy project provided the first data point (baseline) against which trend in squirrel occupancy over time will

Report Section	Comment and Response
	be measured by conducting repeat surveys. Habitat is a requirement for the survival of any organism. The squirrel was originally listed due to the threat of habitat loss. Our habitat change results suggest habitat loss has continued since listing and it is reasonable that continued loss of habitat is not compatible with maintaining Western Gray Squirrel population levels.
	4. This occupancy survey does not use probability-based sampling methods to ensure that estimates of occupancy apply to the entire area of interest (e.g., current range of Western Gray Squirrels). They excluded these peripheral areas, asserted that there was a reduction of detections in peripheral area (which they didn't sample in this study) and assumed the resulting occupancy pattern was suggestive of a population decline and range contraction.
	Our sampling frame concentrated on core Western Gray Squirrel population areas and was stratified within that frame because work during a pilot phase (2015-2017) indicated very low occupancy within peripheral areas (i.e., costly effort for low return). HUCs within the core population areas were selected randomly for survey. The occupancy results provide a baseline against which to compare future survey results; concerning patterns in the occupancy results were the large areas within these cores where squirrels were not detected.
	5. Occupancy rates vary spatially and by year and a baseline will not provide valid estimates of occupancy over time. Should use a probability based stratified random sample.
	We stratified sampling by ecological system proportional to the extent of each system within each survey HUC then randomly selected HUCs within each project area due to limitations on capacity/funding. Occupancy rates do vary spatially and between years, but not to the degree implied. The scale of the assessment required that surveys be concentrated geographically in any given year to make efficient use of access time, with the potential side effect of inflating differences between consecutive years in the same survey period (2018-2020). Therefore this method does provide an adequate measure of the baseline.

Report Section	Comment and Response
	6. No population data to support uplisting. Habitat and occupancy data are used as a surrogate.
	This is true. Collecting population data range-wide proved cost prohibitive. However population size is only one metric. Occupancy also provides a valid measure of population trends. In this case occupancy and habitat change were used not as surrogates, but as valid sources of data for evaluating key indicators of squirrel status and presence of threats.
	7. Multi-landowner coordinated surveys will allow for better understanding WGS occupancy and population trajectories.
	We look forward to expanding cooperation and sampling area, however we do not have that information currently. WAC requirements dictate the timeline for drafting Periodic Status Reviews, which are to be based on best available science and repeated every five years.
	8. Use of canopy cover change classes collapse some of the potential classification error but also make it more challenging to assess uncertainty.
	This is a valid concern, but the approach enables prediction and connectivity at the landscape scale that is more appropriate to the objective.
	9. Areas of habitat gain would likely be more heterogenous, meaning they may not conform to 85% in one canopy cover class and thus not sampled, introducing bias.
	While this could happen, the canopy cover class definitions were broad so the number of plots that may not have conformed to the 85% rule for this reason was likely low.
	10. High level of interannual variability may be expected with sciurids, but implications of the variable occupancy estimate one year to the next were not discussed.
	Noise such as annual variability may be considered over time when evaluating occupancy trends. The 2018-2020 surveys were only a single point. The effort between the two years was relatively

Report Section	Comment and Response
	balanced and an average over the two years of the project. We do not have the sample size to detect annual variability at this time. Moreover, while squirrel numbers do change from year to year, occupancy of primary habitat is likely much less variable over the short term. Research in Washington has found that adult Western Gray Squirrels have generally high survival and exhibit high site fidelity.
	11. Did not mention 2004 Vander Haegen data which showed 90% of sampled harvest areas still had squirrel presence.
	The data referenced here was from a project designed to evaluate the effects of the protection level afforded individual nest trees during timber harvest on continued use of those nest trees by Western Gray Squirrels. The project was not designed to examine occupancy at the site scale and did not evaluate or measure canopy cover change or other parameters that might affect continued use of a site by squirrels. Timber harvest can be compatible with continued use of a stand by Western Gray Squirrels, but this earlier project did not examine the relationship between level of tree removal and continued squirrel presence or occupancy.
	12. Report does not provide an amount of habitat area required to maintain a healthy population.
	This is true. This would require a complex analysis relating habitat quality and quantity to squirrel survival and productivity over time. Such an analysis is possible but not with the data available at this time. Better data are needed on existing stand characteristics and how these translate to habitat quality and squirrel productivity.
	13. Accuracy of between 0.29 and 0.63 for habitat loss based on aerial imagery suggests this method is not sufficient.
	This comment appears to reference Patton's 1996 Master's study and is not well aligned with the nature of the work done by WDFW and does not reflect the expertise of our staff. In fact, orthophotos were used to map all forest cover in Klickitat County in the early 1990s (Klickitat oak map), which was subsequently ground-truthed using randomly placed plots. That mapping effort had an accuracy

Report Section	Comment and Response
	of 79% across 9 categories of cover type and canopy closure. Ability to distinguish open stands (0-25% cover) from those with canopy cover >25% was 85%. Ability to distinguish cover type (conifer, mixed, oak) was 91% (WDFW, unpub. data). Those same staff involved in the mapping of Klickitat County were also involved in the present analysis.
	14. Some protection measures that are being implemented were not identified as squirrel habitat in the analysis.
	This could be due to several factors. The most obvious may be that primary habitat is a subset of the total area of squirrel habitat, so measures enacted in secondary habitat (still important for occupancy/survival/productivity) that do not increase its status to primary habitat would not appear in the results. Additionally, it is likely that forest practice measures being implemented on some sites as protections may be ineffective for retaining/creating primary habitat.
Factors Affecting Continued Existence	15. Didn't account for required and voluntary protections in the habitat change assessment.
	The habitat change assessment was a post hoc analysis of changes in the amount of primary habitat between 1993(1995) and 2017. As such, any actions that resulted in an increase, retention or reduction in primary habitat would be reflected in the results.
	16. Not considering trends in habitat improvement.
	This Periodic Status Review reflects trends since listing. Should habitat improve going forward as a result of habitat improvements, future status reviews will reflect that. Current conservation measures are not being implemented consistently and vary based on landowner participation.
	17. The Periodic Status Review does not account for recent acquisition of timberland.
	We have updated the Periodic Status Review to include this land acquisition and potential benefits for squirrels. However, a land transaction on its own does not mean the land is currently primary habitat for squirrels, nor does it ensure it will remain habitat in the

Report Section	Comment and Response
	future. We look forward to working with these landowners to develop and implement appropriate management plans to benefit Western Gray Squirrels.
	18. PSR says stick nest surveys are not an accurate way to survey for occupancy related to forest management actions. But Vander Haegen and Keren 2021 cite naive estimates from stick nest surveys.
	The PSR states that occupancy based on stick nests can be a misleading indicator of short term population change due to other factors (e.g., disease, ice storms). Over time (5-10 years), real changes in occupancy are likely also to be reflected in the abundance of active nests.
	19. No evaluation on effectiveness or compliance with voluntary management plans since 2010.
	This is true and we agree it's a problem. Additional capacity is needed in order to effectively implement effectiveness monitoring.
General	20. This decision is premature, wait for voluntary actions to mature. When species are uplisted collaborative solutions become more restricted. This recommendation is based on incomplete science. Need to expand collaborative efforts rather than up-listing.
	This is primarily irrelevant to the Periodic Status Review process. According to Washington Administrative Code, the Periodic Status Reviews are summarizing the biological information and preparing a status recommendation based on the biology of the species. This work is based on the best available science. Listing decisions are based on the biological status of the species and an evaluation of threats according to Washington Administrative Code. WDFW welcomes the opportunity to work collaboratively with all landowners to improve knowledge of and management for Western Gray Squirrels in addressing the threats of habitat loss and degradation.
	21. Landowners are reporting increased sightings of Western Gray Squirrels and nests.

Report Section	Comment and Response
	Data indicating increased sightings have not been made available to WDFW for consideration. An increase in anecdotal observations may be a perceived or real change. They may be localized or widespread. They may be the result of management and/or the result of more favorable weather conditions on food and/or survival. Either way changes in squirrel numbers should be reflected in squirrel detections during occupancy surveys as population levels change.
	22. Timber harvest is a more appropriate term than logging.
	Have made this change to be consistent with the industry standard.

WASHINGTON STATE STATUS REPORTS, PERIODIC STATUS REVIEWS, RECOVERY PLANS, AND CONSERVATION PLANS

Periodic Status Reviews

2021 Ferruginous Hawk
2021 Stellar Sea Lion
2021 Gray Whale
2021 Humpback Whale
2021 Greater Sage-grouse
2020 Mazama Pocket Gopher
2019 Tufted Puffin
2019 Oregon Silverspot
2018 Grizzly Bear
2018 Sea Otter
2018 Pygmy Rabbit
2017 Fisher
2017 Blue, Fin, Sei, North Pacific Right, and Sperm Whales
2017 Woodland Caribou
2017 Sandhill Crane
2017 Western Pond Turtle
2017 Green and Loggerhead Sea Turtles
2017 Leatherback Sea Turtle
2016 American White Pelican
2016 Canada Lynx
2016 Marbled Murrelet
2016 Peregrine Falcon
2016 Bald Eagle
2016 Taylor's Checkerspot
2016 Columbian White-tailed Deer
2016 Streaked Horned Lark
2016 Killer Whale
2016 Western Gray Squirrel
2016 Northern Spotted Owl
2016 Snowy Plover

Conservation Plans

2013 Bats

Recent Status Reports

2021 Oregon Vesper Sparrow
2019 Pinto Abalone
2017 Yellow-billed Cuckoo
2015 Tufted Puffin
2007 Bald Eagle
2005 Aleutian Canada Goose
1999 Northern Leopard Frog
1999 Mardon Skipper
1999 Olympic Mudminnow
1998 Margined Sculpin
1998 Pygmy Whitefish
1997 Aleutian Canada Goose

Recovery Plans

2020 Mazama Pocket Gopher
2019 Tufted Puffin
2012 Columbian Sharp-tailed Grouse
2011 Gray Wolf
2011 Pygmy Rabbit: Addendum
2007 Western Gray Squirrel
2006 Fisher
2004 Sea Otter
2004 Greater Sage-Grouse
2003 Pygmy Rabbit: Addendum
2002 Sandhill Crane
2001 Pygmy Rabbit: Addendum
2001 Lynx
1999 Western Pond Turtle

Status reports and plans are available on the WDFW website at: http://wdfw.wa.gov/publications/search.php